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ERIGENIA is named for *Erigenia bulbosa* (Michx.) Nutt. (harbinger-of-spring), one of our earliest blooming woodland plants and a species that serves as a promise of things to come. The first issue was published in August 1982.

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ABSTRACTS - All papers should include an abstract with up to 250 words. The ABSTRACT should state goals, principal results, and major conclusions of the paper.

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Glen Spelman Winterringer (6 October 1906 – 31 January 1974)

Kathleen Marie Garness[1]

We owe so much to the work of previous generations of botanists, and often their work is almost forgotten. One of these Illinois botanical luminaries was Glen Spelman Winterringer, who was manager and ultimately Curator of the botanical holdings at the Illinois State Museum from 1949 to 1973 (Figure 1). According to the ISM database, Glen collected an impressive 22,391 specimens in the field for their herbarium during his tenure! And were it not for his untimely tragic death in 1974, it's likely he would have collected many more.

Glen grew up in Arcola. IL, in a house on West Washington St. (Arcola, IL Census 1910, 1940), with few amenities other than a wood burning cook stove. Glen's father, John Winterringer (born 1871) ran a drayage business, hiring out horse-drawn wagons and transporting goods from one place to another. When his first wife Flora died and left him with two young children, he married Martha (Mattie) Elizabeth Spelman in January 1906. Glen was born exactly nine months to the day later, and his younger brother, Ray, five years after that.

Glen lost his father when he was only 12 and Ray was 7, so Mattie largely raised the children on her own, working as a seamstress making graduation gowns. She also worked in a factory making traditional brooms from broom corn, the industry that put Arcola on the map. Glen graduated from Arcola High School in 1925 and served in the U.S. Army as a Technical Sergeant (U.S. Army Enlistment Records 1938-1946). He graduated from Illinois College in Jacksonville, then spent time teaching high school in Arcola and soon after earned his Ph.D. in botany from the University of Illinois at Urbana in 1949. His mentor and dissertation advisor was Dr. Arthur Vestal. His brother Ray went to Purdue to become an electrical engineer. But they always made sure their mother was comfortable – even installing indoor plumbing and electricity in the house for her, along with a gas furnace and eventually a modern electric range.

Arcola is quintessential small town America. In Glen's nephew Lee's words, "follow the Illinois Central South railroad tracks east to some churches, and then west to where Grandma and the boys lived. You could walk from Grandma Mattie's house to downtown Arcola to shop." The clip-clop of the Amish horse drawn carriages on the cobbled brick street was – and still is – a familiar sound. And there is still a hitching post behind the Arcola newspaper! Honesty, excellence, enterprise, were all qualities Glen absorbed in Arcola.

Figure 1. Glen S. Winterringer, date unknown.

Hired by the Illinois State Museum (ISM) in 1949, Glen was promoted to Curator of Botany in 1956. He lived nearby, on south Second Street in Springfield. He helped design the exhibits at ISM, making sure the botanical specimens used were correct and well-placed.

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It was his mission to get a record of what occurs and where, collecting many new species for the museum. Consequently, Glen spent most of his days out in the field, looking for new species and occurrences of native plants, often in remote areas, without any of our now-essential navigational aids, such as cell phones and GPS units. Fortunately, his memory of species and locations was encyclopedic. In this regard, Dr. Winterringer continued the legacy of botanists such as Dr. Vasey, Elihu Hall, John Wolf, Dr. George Fuller, and Vestal, all of whom contributed to the holdings at the Illinois State Museum and other agencies.

In addition to his 22,391 collections deposited at the Illinois State Museum, the University of Illinois herbarium has 49 specimens Winterringer collected or was a co-collector. He also deposited specimens at the Field Museum, Iowa State University, Utah State University, J.F. Bell Museum of Natural History Herbarium, Mississippi State University, Missouri Botanical Gardens, New York Botanical Gardens, Eastern Illinois University, University of Arizona, University of Colorado, University of Florida, University of Mississippi, University of North Carolina Chapel Hill, University of Wisconsin-Madison, and Western Illinois University.

Interestingly, Glen's mentor, Dr. Arthur Vestal, was brother-in-law to Dr. Norma Pfeiffer, who discovered and described *Thismia americana* (thismia), an Illinois endemic species known only from the Calumet region (now considered extinct). Glen sometimes botanized nearby the historic thismia population in Riverdale, Illinois. Was Glen trying to relocate this cryptic plant? We'll never know!

Outspoken and hardworking, Glen became noted for his research and collaborated with staff at the Illinois Natural History Survey and with universities nationwide. The community of scientists and botanists with whom he worked, and the natural areas he loved, were like another family to him. Glen's publications on Illinois flora inspired many people to get out and look for uncommon species as well as reminding people of plants they had seen outdoors. Readers would sometimes contact the museum to inform the staff of new locality records for species, particularly orchids. Such interactions led Glen and other museum staff to become aware of a need for providing educational resources to the public. A noteworthy outcome of this realization is the meticulously-researched *Wild Orchids of Illinois* (Winterringer 1967). Two of his notable orchid collections that contributed to this volume were *Spiranthes grayi*, now known as *S. tuberosa* (little ladies' tresses), recorded from on a rocky ledge on Williams Hill one mile west of Herod, Pope County, 17 August 1948, and *Hexalectris spicata* (crested coral root), found on a rocky hillside near Prairie du Rocher, Randolph County, 13 July 1949. Neither species previously had been recorded for Illinois. A similar contribution on aquatic plants of Illinois (Winterringer and Lopinot 1966) discussed how species distribution had been greatly affected by created ponds and lakes.

According to colleague Ed Armstrong (Illinois State Register, 4 February 1974), Glen collaborated with Drs. C. Neville Jones and George Fuller in the preparation of *Vascular Plants of Illinois* (Jones and Fuller 1955) and five years later he and Dr. Robert Evers compiled collections data from many botanists resulting in a supplement to this volume, *New Records for Illinois Plants* (Winterringer and Evers 1960). This contribution filled many species distribution gaps for the Illinois flora.

As a conservationist, Glen was very concerned with the loss of natural areas. His paper with Victor Shelford, *The Disappearance of an Area of Prairie in the Cook County, Illinois Forest Preserve District* (Shelford and Winterringer 1959) described in detail the degrading human influence on our natural areas, and also discussed the impacts of the absence of fire in our prairies once development accelerated. According to Shelford and Winterringer (1959), the consensus of expert opinion at the time recommended burning every three years, with one third of the prairie burnt each year so as to avoid impact on the animals in the other two thirds.

Glen was an enthusiastic supporter of younger botanists, such as Dr. Charles Sheviak, whose authoritative work An Introduction to the Ecology of the Illinois Orchidaceae (Sheviak 1974) was a much-needed addition to our literature, and Dr. Robert Mohlenbrock, who recounts that "We spent quite a bit talking about blufftop flora of southern Illinois, which was a specialty of his. He introduced me to the famous Springfield Horseshoe for lunch on one of my visits." Winterringer is credited in several of Dr. Mohlenbrock's volumes of the native plants of Illinois.

Glen also knew Illinois botanist John Schwegman. John remembers "I moved to Springfield in January of 1972, just before he retired, and my office was just across the street. I was interested in unique small plant habitats like sandstone glades and seep springs and I would go over and visit with him and Al Koelling who was training to take over when Glen retired. We discussed the sandstone glades of southern Illinois that he studied for his dissertation. Sometimes I would go over at noon unannounced and he would be napping on a big table they had in the herbarium to lay out plant specimens (Figure 2). Koelling told me that it was common for him to take a noontime nap on the table! Glen told me that he had always wanted to see Australia and one of the first things he did upon retirement was to visit Australia."

What sort of person was Glen? His nephew Lee spent many a summer in Arcola and visited Glen at least once at his house in Springfield. Lee even went botanizing with Glen once at Illinois Beach State Park for two days. Lee recounted how Glen 'was a cat person'

Figure 2. Glen in Illinois State Museum herbarium, July 1967, standing by specimen sorting table which on occasion would accommodate his noontime nap.

and 'single-minded' in his focus. "We got along pretty good, though." In later years, Glen developed a reputation for being cantankerous, but most of his close colleagues overlooked that because they understood him and his passion for conservation of natural areas.

Glen married late, in his mid-50s, to Bernice Ruth White, but the marriage didn't last. Evidently, it takes a very patient sort of person to marry a peripatetic botanist! Glen retired from the Illinois State Museum in 1973. He loved to travel and greatly looked forward to his planned trip the following year to Australia, surely an enjoyable trip. Alas, on the return flight, departing from Auckland, New Zealand, his plane crashed during a thunderstorm in Pago Pago, American Samoa – a scientist's life tragically cut short.

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Arcola, IL census 1940. Records indicate Glen in the household of his mother Martha: https://www.familysearch.org/ark:/61903/1:1:KW42-JYN?from=lynx1&treeref=LYKL-T29

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Breaking Physical Seed Dormancy of Three *Baptisia* Species with Chemical Scarification

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Abstract: Prior research has demonstrated that acid scarification is effective at breaking physical seed dormancy. Exposing seeds to concentrated base solutions should have similar effects to acid scarification due to their corrosive properties, but such treatments are rarely investigated. Consequently, we tested acid and base scarification in three species in the wild indigo (*Baptisia*) genus: *Baptisia alba*, *B. australis*, and *B. bracteata*. Seeds were scarified in either concentrated 98% sulfuric acid or 1M NaOH for different time intervals (20, 40, 60, and 90 min) and seedling emergence recorded 21 days after exposure. Species, chemical treatment, and time of exposure were all highly significant predictors ($p < 0.0001$) of emergence. We found evidence of an interaction between species identity and time of exposure ($p < 0.01$). *Post hoc* tests suggested acid was the most effective treatment overall, but both acid and base treatments promoted higher emergence compared to controls ($p < 0.1$). We recommend higher than tested chemical concentrations or longer exposure times for *B. alba* and *B. bracteata* seeds due to their demonstrated resilience to physical damage. To reliably break dormancy, we recommend acid exposure times for 135, 40, and 60 minutes for *B. alba*, *B. australis*, and *B. bracteata*, respectively. Our data support prior findings regarding the efficacy of acid scarification, and confirm that chemical scarification can quickly and reliably overcome strong physical dormancy mechanisms.

Introduction

Baptisia (Fabaceae) species found in eastern North America are reliably associated with native plant communities (Taft *et al*. 1997). Their propagation for prairie restorations and native gardens has generated interest due to their showy inflorescences and value to native pollinators (Ault 2003; Gardner 2011; Padmanabhan et al. 2017). Like many prairie forbs, *Baptisia* species possess dormancy mechanisms to prevent premature seed germination (Sorensen and Holden 1974). Commonly, cold moist stratification is used to overcome seed dormancy for propagating forbs (Bratcher *et al*. 1993). However, past research has indicated that *B. australis* can be more difficult to germinate compared to other forbs (Hitchmough *et al*. 2004). Other *Baptisia* species may have stronger dormancy mechanisms than *B. australis*, taking years to germinate and emerge under natural conditions (Gardner 2011).

This difficulty in promoting germination within *Baptisia* is caused by physical dormancy due to high water impermeability of the seed coat, a dormancy type characteristic of the Fabaceae family (Baskin *et al*. 2000). Physical dormancy in Fabaceae is caused by a dense layer of palisade layers containing Malphigian cells on the seed coat along with the presence of substances impermeable to water; these must be damaged for water to reach the embryo and facilitate germination (Baskin 2003). While natural conditions such as freezing, thawing, fire, and animal digestion can increase the permeability of the seed coat, artificially damaging seeds can similarly increase seed coat permeability (Baskin and Baskin 2014). Mechanical scarification is one way to overcome physical dormancy, but it can be time consuming for large seed numbers and potentially damage seeds (Baskin and Baskin 2014). Moreover, standardizing the degree of damage to the seed coat can be difficult. Because acid scarification can damage seeds efficiently and homogenously, and because past studies have utilized acid scarification to break the dormancy of other native species (Stewart and McGary 2010), we tested chemical scarification on native *Baptisia* seed.

Previous studies have used chemical scarification in *Baptisia*, including *B. australis* (Boyle and Hladun 2005), *B. hirsuta* (Thetford 1999), and *B. tinctoria* (Voss *et al*. 1994). However, *B. alba* and *B. bracteata*, currently

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lack published studies on proper chemical scarification protocols. Since Boyle and Hladun (2005) demonstrated effective acid scarification treatments for *B. australis*, we expanded on their work and applied their protocols to two additional *Baptisia* species: *B. alba* and *B. bracteata.* We also retested *B. australis* to verify we could replicate results from Boyle and Hladun (2005). Additionally, we tested another type of chemical scarification, base scarification, on all three species. Base scarification used corrosive sodium hydroxide (NaOH). Using bases as chemical scarifying agents has been performed (Yeo and Dow 1978), but using strong acids seems to be far more prevalent for promoting germination and emergence. In our experiment, we measured seedling emergence after chemical scarification as a conservative proxy of germination.

Our objectives were to: 1) determine the relative efficacy of acid and base scarification for overcoming seed dormancy, 2) compare exposure-emergence responses among the species, and 3) establish ideal chemical scarification treatment times for each of the three species for potential commercial or private use.

Materials and Methods

Species selection

Baptisia species are potential target species for restoration or horticultural uses because of their showy racemes and ecological value to wildlife. The three study species have wide geographic ranges throughout the eastern half of the United States. In selecting species, we chose species native to midwestern tallgrass prairies that were also commercially available. Nomenclature follows Mohlenbrock (2013). *Baptisia alba* (L.) Vent (white wild indigo), also known as *B. lactea* or *B. leucantha*, is a 1-1.5m high herbaceous perennial with white blossoms on erect racemes (Rickett 1966; Hilty 2017). *Baptisia alba* is found in prairies to open woods from Ohio to Minnesota and Nebraska, and southward to Mississippi and Texas. *Baptisia australis* (L.) Vent (blue wild indigo) is an herbaceous perennial up to 1.5m tall that inhabits open areas from Pennsylvania to Indiana and southward to Georgia and Tennessee. Racemes of blue-purple blossom in late spring and are a popular food source for bumblebees. *Baptisia australis* is also used by the horticultural industry for producing *Baptisia* hybrids and cultivars (Ault 2003). *Baptisia bracteata* (Ell.) Vent (cream wild indigo) is a stout herbaceous legume at 0.3-1m tall with a sprawling growth form. It has racemes of cream-colored flowers which bloom earlier than *B. alba* and *B. australis*. *Baptisia bracteata* is found in high quality prairie and savanna remnants and produces low seed sets compared to *B. alba* despite occupying similar habitats (Peterson *et al*. 2013). It ranges from Michigan to Minnesota and Nebraska, and south to Kentucky, Louisiana, and Texas. Due to these characteristics, *B. bracteata* seed is expensive, even by prairie forb standards; seed prices are commonly over $1,000/lb, making consistent germination rates desirable.

Seed source

Unscarified seeds of all three species were purchased from Prairie Moon Nursery (Winona, MN) in May 2016. Seeds were stored indoors at room temperature until experimental trials began in June 2016.

Scarification procedure

Seeds were exposed to a stock solution of 98% sulfuric acid (i.e. 18M H_2SO_4) or a prepared solution of sodium hydroxide (1M NaOH) for various time intervals and then planted in seedling trays to determine emergence. Scarification trials were conducted by species with individual species receiving treatment on different days. On a given day, approximately 80 seeds of a species were counted and randomly assigned into one of nine treatment groups. These treatment groups included both acid and base treatments over four exposure times (20min, 40min, 60min, or 90min) as well as a control that soaked seeds in tap water for 60min. To each of our four 100mL beakers, 30 mL additions were made of 98% H_2SO_4 for acid treatments, 1M NaOH for base treatments, and tap water for the control. A follow-up trial was conducted for *B. alba* seeds only, due to a linear increase in emergence rates from the initial trial times (see Results) using the same general procedures. This subsequent trial included extended acid scarification exposure times (45min, 90min, 135min, or 180min).

Beakers containing each solution and seeds were placed on magnetic stir plates with stir bars and run on low-medium speed to expose the seeds to the treatment solution. After each treatment, seeds were removed from the beaker, put into a metal sieve, and rinsed in tap water for three to five minutes. Seeds were then removed from the tap water wash and planted within three hours of treatment. Scarification procedures were run in June 2016 through July 2016. The follow-up trial for *B. alba* was run in September 2016.

Planting protocol

Planting trays with 72 cells (3.9cm width × 7.6cm depth) were purchased from A.M. Leonard Horticultural Supply Company (Piqua, OH). Cells were filled tightly with Miracle Grow® garden soil. Each tray contained seed from just one species for all of its nine treatments. For *B. australis*, ten trays were planted overall (total *B. australis* seeds planted = 715). Fifteen trays were planted for *B. alba* (total seeds planted = 1050), ten trays for the first trial and five trays for the

Table 1: Effect of 18M sulfuric acid scarification exposure on emergence of three *Baptisia* species. Note that the values for the control and acid 90min for *B. alba* were pooled for the two trials. *Bolded emergence percentages indicate the highest recorded emergence for each species across all treatments.

Acid treatment	Number emerged/ total treated for *B. alba*	% emerged for *B. alba*	Number emerged/ total treated for *B. australis*	% emerged *B. australis*	Number emerged/ total treated for *B. bracteata*	% emerged *B. bracteata*
Control	6/116	5.2	14/80	17.5	2/48	4.2
20min	8/80	10.0	65/79	82.3	9/46	19.6
40min	14/80	17.5	72/80	**90.0***	13/44	29.5
45min	10/37	27.0	-	-	-	-
60min	16/80	20.0	64/78	82.1	23/47	**48.9***
90min	42/116	36.2	56/79	70.9	17/44	38.6
135min	14/37	**37.8***	-	-	-	-
180min	9/35	25.7	-	-	-	-

second trial (see Table 1). *Baptisia bracteata* had six trays planted (total *B. bracteata* seeds planted = 411); less seed was available for this species due to cost. Within each planted tray, eight seeds from each of the nine treatments (i.e. eight treatment replicates per tray, seed availability permitting) were randomly assigned to cell numbers. One seed was then planted in each corresponding cell at a 2cm depth and covered lightly with soil. The different treatments were marked using toothpicks coded using colored tape. Trays were labelled and put in indirect sunlight in a temperature-controlled greenhouse (approximately 18-24°C) at the University of Illinois at Springfield (39.7287° N, 89.6174° W) and gently watered. Trays were manually watered with tap water every one to two days to keep soil consistently moist over the trial period.

Data collection

Emergence rates were measured by counting the number of seedlings that emerged until 21 days after planting. Care was taken to watch the cells in order to record seedlings which emerged prior to the final 21-day count. Seedlings found dead (e.g. root penetration visible but cotyledons not present) were assumed to be a positive emergence event and were included in the final 21-day count.

Data analysis

Data analysis was conducted using R v. 3.4.1 (R Core Team 2017). Binomial logistic regression was performed with species, solution type (acid versus base), and exposure time as factors, as well as their respective interaction terms. An analysis of deviance was conducted on the logistic regression model using a χ^2 test to determine which factors were significantly associated with emergence. For this model, the control solution treatments were excluded because of the standardized time of exposure (60min) to the water solution. We then performed a second logistic regression across solution types and species for 60-minute exposure times to compare all three solution types across species. This model was followed by Tukey's HSD to differentiate the efficacy of solution types and control for experiment wise type I error. Treatment groupings were then generated using the *emmeans* package to interpret the Tukey's HSD results.

RESULTS

Acid scarification treatments were generally more reliable at promoting emergence than base scarification, with intermediate exposure times showing the highest emergence rates (Figs. 1-3, Tables 1 and 2). Maximum emergence was observed within acid solution treatments, with 90% being the highest proportion of emerged seedlings from *B. australis*. In contrast, *Baptisia alba* and *B. bracteata* had comparatively modest maximum emergence percentages at 37.8% and 48.9%, respectively. The second trial for *B. alba* suggested the extended acid scarification exposure times had equal or greater success at promoting emergence compared to shorter exposure times (Fig. 1). Our logistic regression identified predictors of seed emergence (Table 3): species identity, solution type, and time of exposure to the solution were highly significant ($p < 0.001$, Table 3). We found no significant interaction of species identity*solution type or solution type*time of exposure ($p > 0.1$, Table 3). Our model however did identify a significant interaction of species identity*time of exposure ($p < 0.001$, Table 3). The separate logistic regression, run for 60-minute exposure times only, indicated a marginally significant effect of a species

Table 2: Effect of 1M NaOH scarification exposures on the emergence of three *Baptisia* species. Note the higher sample sizes for *B. alba* due to pooling results of its two trials.

Base treatment	Number emerged/ total treated for *B. alba*	% emerged for *B. alba*	Number emerged/ total treated for *B. australis*	% emerged *B. australis*	Number emerged/ total treated for *B. bracteata*	% emerged *B. bracteata*
Control	6/116	5.0	14/80	17.9	2/48	4.2
20min	4/113	5.0	50/80	62.5	6/43	14.0
40min	7/117	6.0	52/80	65.0	5/47	10.6
60min	9/119	7.6	50/80	62.5	6/48	12.5
90min	17/120	14.2	55/79	69.6	4/44	9.1

Table 3: Summary of the logistic regression model for all treated seeds of the three study species. "***" indicates significance at $p < 0.001$.

Factor	Df	Deviance	Residual df	Residual deviance	Pr(>Chi)
NULL			1852	2418.0	
Species identity	2	597.02	1850	1821.0	<0.001***
Solution	1	75.53	1849	1745.5	<0.001***
Time	1	15.35	1848	1730.1	<0.001***
Species identity*Solution	2	1.64	1846	1728.5	0.440
Species identity*Time	2	22.52	1844	1705.9	<0.001***
Solution*Time	1	0.13	1843	1705.8	0.719

identity*solution type interaction ($p < 0.1$, Table 4). Treatment groupings from the HSD tests for solution type indicated a greater efficacy of both chemical scarification treatments compared to the control for promoting emergence, with acid having the greatest effect (Table 4).

DISCUSSION

Chemical scarification promoted reliable germination and emergence in these three *Baptisia* species. The responses toward chemical scarification exposure times varied among the species, as indicated by our significant

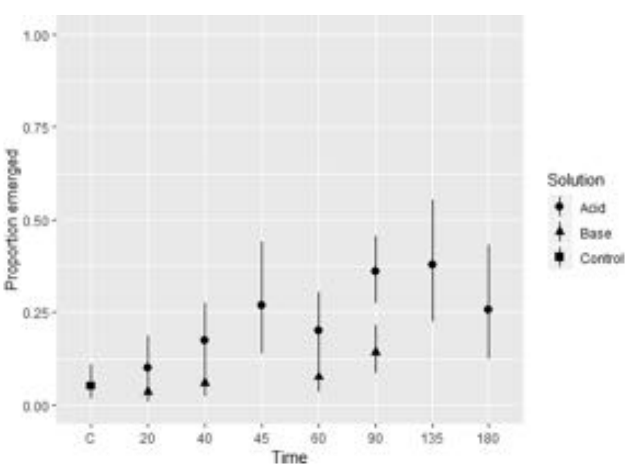

Figure 1. Emergence of *B. alba* following chemical scarification at various exposure times. Error bars are 95% confidence intervals.

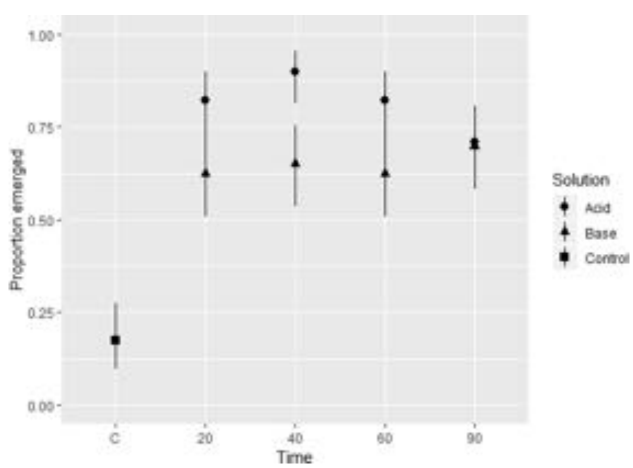

Figure 2. Emergence of *B. australis* chemical scarification at various exposure times. Error bars are 95% confidence intervals.

Table 4: Summary of the logistic regression model for seeds which were exposed to different solution types for 60 minutes. We separated the effects of solution type by running a post-hoc Tukey test. Different letters in Tukey's HSD groupings indicate those solution types had significantly different ($p < 0.05$) effects to emergence across all three species at the 60 minute exposure time. "***" indicates significance at $p < 0.001$; "." indicates significance at $p < 0.1$.

Factor	Df	Deviance	Residual df	Residual deviance	Pr(>Chi)	Solution type	Proportion overall emerged ± standard error	Tukey's HSD groupings
NULL			695	816.00		Control	0.0895±0.018	a
Species identity	2	135.31	693	680.69	<0.001***			
Solution	2	109.87	691	571.51	<0.001***	Base	0.2752±0.025	b
Species identity* Solution	4	9.05	687	562.46	0.060.	Acid	0.5033±0.032	c

species identity*time of exposure interaction. Upon further investigation, this result appears to be driven by a unique response by *B. alba*. *Baptisia australis* and *B. bracteata* emergence proportions both levelled off or even decreased with increasing exposure times, whereas *B. alba* emergence increased linearly across the same range of exposure times (20, 40, 60, and 90min exposure times). Species-specific exposure responses are not surprising considering Baskin and Baskin (2014) provide a list of congeners, many of which have varying exposure times in sulfuric acid to yield maximum germination. For example, Baskin et al. (1998) found a differing response to sulfuric acid scarification for breaking the physical dormancy between two Caesalpinoid legumes: *Senna marilandica* and *Senna obtusifolia*. Similar to differences found between *B. alba* and *B. australis* in our study, *Senna marilandica* benefited from double the exposure time for maximum germination compared to *S. obtusifolia*.

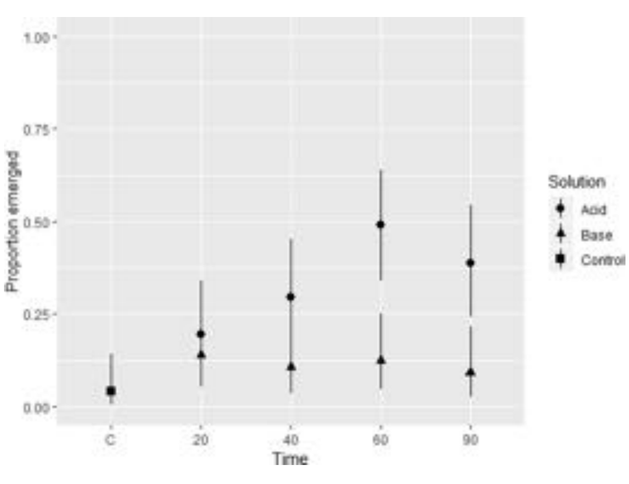

Figure 3. Emergence of *B. bracteata* chemical scarification at various exposure times. Error bars are 95% confidence intervals.

Our treatments had greater success of promoting emergence with *B. australis* compared to the other two species. Results for the acid scarification treatment in *B. australis* were similar to those found by Boyle and Hladun (2005), indicating that we successfully replicated their findings. We had more success with promoting germination and emergence in *B. australis*, with emergence being particularly high (>80%) after acid scarification for 20, 40, and 60 minutes. Our results also suggest that acid scarification can bypass the weeks of cold moist stratification needed to break the dormancy of *B. autralis* (see Bratcher *et al*. 1993). Overall, our data support the conclusions of Boyle and Hladun (2005) that sulfuric acid scarification can promote the rapid and uniform germination of large numbers of *B. australis* seeds.

We found that *B. alba* and *B. bracteata* responded less favorably to our chemical scarification treatments compared to *B. australis*; these two species did not yield emergence above 50%. Although emergence percentages in these two species were lower than for *B. australis*, they were still much higher than published values *B. hirsuta*, which only yielded 9% germination after 3 weeks following 15, 20, and 25 minutes exposure to sulfuric acid (Thetford 1999). Hence, breaking physical dormancy of *B. alba* and *B. bracteata* with sulfuric acid has intermediate success compared to other studied *Baptisia* species. Since Voigt (1977) found mechanical scarification to yield 100% germination among forty seeds of *B. alba*, chemical scarifications may be inferior treatments for this species. The low emergence responses observed in *B. alba* and *B. bracteata* could be due to higher testa lignification or lower seed viability compared to

B. australis (Boyle and Hladun 2005). Chemical scarification could have also caused embryo mortality among the study species, especially considering how emergence levelled off or declined in our acid scarification results.

Emergence for our study species might have improved if we had paired additional and different treatments to the chemically scarified seeds. For example, other studies have paired chemical and mechanical scarification with cold moist stratification in their study species (Stewart and McGary 2010; Gardner 2011; Pipinis *et al*. 2011). Regardless of the proximate cause for the lower emergence proportions in *B. alba* and *B. bracteata*, acid scarification was still fairly reliable at breaking dormancy. Other studies suggest that prairie species with strong physical dormancy mechanisms may have below 50% germination, regardless of treatment types (Stewart and McGary 2010).

The base solution promoted less emergence across all species compared to the acid. While base scarification promoted relatively high emergence in *B. australis*, the solution of base was not as concentrated as the sulfuric acid treatment (1M vs 18M) and failed to yield consistent emergence in *B. alba* and *B. bracteata*. We recommend either drastically increasing base concentrations or increasing exposure times if base scarification is used for these two species. Nonetheless, both chemical scarification methods were superior to the control. To optimally overcome the study species' physical dormancy, we recommend *B. alba* be treated in 98% H_2SO_4 for 135 minutes; *B. australis* should be treated for 40 minutes; and *B. bracteata* should be treated for 60 minutes.

CONCLUSION

Emergence varied among species, among the type of chemical treatment, and from the duration of exposure to the chemical agent. For *B. australis*, both acid and base methods yielded a large proportion of emerged seedlings. However, our treatments for *B. alba* and *B. bracteata* had more modest success. This demonstrates the importance of performing such tests across multiple species in a genus due to variation of a method's efficacy within a given genus. Chemical scarification is a viable option to break physical dormancy in *Baptisia* species and can be used for fast and consistent results from a large number of seeds in commercial or private use.

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Status and Distribution of *Mimosa quadrivalvis* L. var. *nuttallii* (DC.) Barneby (Nuttall's Sensitive Briar, Fabaceae) in Illinois

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Abstract: We conducted herbaria searches to locate specimens of *Mimosa quadrivalvis* var. *nuttallii* (DC.) Barneby (Nuttall's sensitive briar) from Illinois. This taxon is common in the Western Plains but is rarely observed in Illinois where populations are known from sites in Bureau, DuPage, Fayette, Kane, Morgan, Peoria, and Winnebago counties. We identified seven potential locations based on herbaria searches. Subsequent field surveys revealed the presence of two extant populations of ten and one individuals in DuPage and Fayette counties, respectively. The Bureau and Kane County populations are extirpated, and populations in Morgan, Peoria, and Winnebago counties could not be relocated. Nuttall's sensitive briar is considered native to central Illinois, but its nativity in the northern part of the state is uncertain. This taxon is currently listed as endangered in Illinois.

Introduction

Mimosa quadrivalvis var. *nuttallii* (DC.) Barneby (Nuttall's sensitive briar, Fabaceae), commonly known as cat's claw and devil's shoestring, is an herbaceous, perennial plant characterized by a procumbent growth habit and stems having numerous yellowish, recurved, internodal prickles; pinnately compound leaves; axillary, globose heads of minute, rose-colored flowers; and long, narrow, prickly, four-valved fruits (Gleason and Cronquist 1991; Mohlenbrock 2014). Nuttall's sensitive briar is known from dry, sandy, and gravelly soils in open woodlands, glades, and prairies from Illinois west to Nebraska, and North Dakota south to Texas (Gleason and Cronquist 1991). This plant, also known by the synonyms *Schrankia nuttallii,*(DC.) Standl., *S. uncinata* Willd., *Morongia uncinata* (Willd.) Britton*, Mimosa nuttallii* (DC.) B. L. Turner, and *Leptoglottis nuttallii* DC., blooms from June through September throughout its range (Gleason and Cronquist 1991; Mohlenbrock 2014). Its leaves fold when touched, giving rise to its common name.

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This taxon is critically endangered in Iowa but is present in Missouri in all but the northeast and southeast counties (Eilers and Roosa 1994; Yatskievych 2006). Nuttall's sensitive briar lies at the eastern edge of its range in Illinois where this species is known from seven counties in the central and northern parts of the state and is listed as endangered due to its limited distribution and small populations (Illinois Endangered Species Protection Board 2020; Mohlenbrock 2014). The purpose of this study was to determine the habitat and current distribution of Nuttall's sensitive briar and clarify the nativity of this species throughout Illinois.

Methods

We reviewed literature and visited in-state and out-of-state herbaria to identify collections of Nuttall's sensitive briar from Illinois. The herbaria searched were at Northern Illinois University (DEK), Eastern Illinois University (EIU), Field Museum of Natural History (F), University of Illinois (ILL), Illinois Natural History Survey (ILLS), Illinois State Museum (ISM), Illinois State University (ISU), Knox College (KNOX), Missouri Botanical Garden (MO), Natural Land Institute (NLI), Rockford College (RCH), and Western Illinois University (MWI). We also analyzed specimen label data to determine the date of collection, location, habitat, collector's name, and associated plants as available (see Appendix).

Field studies were conducted at historic collection sites during 2019 to determine the current statewide distribution and population status of this taxon, and to more accurately define its habitat and nativity. Plants were counted and notes taken on the substrates and adjacent vegetation. Specimens were collected and deposited in the herbaria of Eastern Illinois University (EIU) and the Morton Arboretum (MOR). Nomenclature follows Mohlenbrock (2014), and Wilhelm and Rericha (2017).

RESULTS

We identified eighteen herbarium specimens from Bureau, DuPage, Fayette, Kane, Morgan, Peoria, and Winnebago counties. The initial collections by McDonald in 1900 and 1901, and Chase in 1921 apparently were from glacial drift hill prairies at the Horseshoe Bend Overlook of Kickapoo Creek, a small tributary of the Illinois River in Peoria County. Thirty-seven years passed before E. W. Fell collected a specimen from gravelly prairie (23 June 1958) within the Greater Rockford Airport in Winnebago County. Koelling found Nuttall's sensitive briar (17 September 1965) growing along a railroad right-of-way in Bureau County, and Rexroat made eight collections from "sandy, loess bluffs" along the eastern side of the Illinois River in Morgan County in the late 1960s (see Appendix). The Kane County collection by H. E. Eilers (5 July 1970) was taken from a degraded hill prairie at the former Fellowship Deaconry, and the DuPage County collections by Lampa (7 August 1984) and Kobal and Lampa (3 July 2019) are from the West Chicago Prairie. A recent collection of Nuttall's sensitive briar by McClain (10 June 2019) from the Horn Prairie Grove Land and Water Reserve in Fayette County represents a new locality for this species in the state.

Herbaria label data indicated plants were growing on sandy loess bluffs (8 specimens), prairie (2 specimens), and one each from gravelly slope, hill prairie, dry sandy soil, gravel bluff, sloping gravel prairie, and dry hillside. One specimen lacked data, and another was taken from a railroad right-of-way. The collection dates ranged from June 7 to September 29, with most specimens collected during September. The Bureau and Kane county populations are extirpated, and no plants were found in Morgan, Peoria, and Winnebago counties where suitable habitat remains. Ten plants were located in the West Chicago Prairie in DuPage County, and a single plant was found in the Horn Prairie Grove Land and Water Reserve in Fayette County.

DISCUSSION

The nativity of sensitive briar in Illinois has been questioned since its discovery in 1900. The initial collector, F. E. McDonald, considered this plant adventive to the Peoria area, perhaps because it was a western plains species previously unknown from Illinois. Botanist V. H. Chase visited the same collection site 20 years later, but he considered the plant to be naturally occurring because of its presence in native glacial drift hill prairie. Sixteen of the eighteen sensitive briar collections from Illinois were taken from native prairie remnants. One specimen was from a railroad right-of-way, suggesting an adventive population. Railroads are well known dispersal routes for a great variety of vascular plant species (Muhlenbach 1979).

Past land use is sometimes beneficial in determining nativity. Fell (1962) considered Nuttall's sensitive briar adventive to Bell Bowl Prairie within the Greater Rockport Airport in Winnebago County. He thought seed may have been introduced to the site by the hundreds of horses and mules stationed here when the location was used as a World War I training camp. Seed may also have been introduced at a former stockyard at the West Chicago Prairie in DuPage County. Livestock can transport seed considerable distances by ingesting and passing them in dung, or by the attachment of seed to skin or fur (Chuong *et al*. 2016). The prickly fruits of Nuttall's sensitive briar appear to be well adapted for clinging to fur.

Plant populations widely disjunct from their primary range may indicate adventiveness, but these populations should be carefully evaluated. For example, a population of slivery bladderpod (*Physaria ludoviciana* (Nutt.) O'Kane and Al-Shehbaz), the only one in Illinois, is considered native to a sand dune in Mason County known as Devil's Tower located in the Henry A. Gleason Nature Preserve. The nearest population for this plant is 700 km north in Redwing, Minnesota (Coons *et al*. 2000). Prairie trout lily (*Erythronium mesochoreum* Knerr), another western plains species, was not discovered in Illinois until 1980 despite its presence in at least seven counties (McClain *et al*. 1999). Illinois remains the only state east of the Mississippi River that has populations of this plant. Likewise, Illinois is the only state east of the Mississippi River thought to have naturally occurring populations of Nuttall's sensitive briar. Its presence in Illinois should not be unexpected due to its presence in all but the northeast and southeast corners of the adjacent state of Missouri (Yatskievych 2006).

The presence of flora from the same geographic region as Nuttall's sensitive briar may also help determine nativity. Fell (1962) listed several western plants (*Artemisia dracunculus* L., *Froelichia gracilis* Moq., *Ratibida columnifera* (Nutt.) Wooton and Standl., *Buchloe dactyloides* (Nutt.) Englm., and *Chloris verticillata* Nutt.) that were present in Bell Bowl Prairie, but absent in other gravel prairies in the Rockford area of Winnebago County, as evidence for the potential adventive status of Nuttall's sensitive briar at this site (Fell and Fell 1956). Wilhelm and Rericha (2017) also mention the presence of western plains plants (e.g., *Baptisia* *australis* (L.) R. Br.) within the West Chicago Prairie in DuPage County, and the most recent collection of this taxon from this this prairie lists *Baptisia australis* as an associate (Appendix).

Determining the nativity of organisms is not a precise process, and it is sometimes impossible to determine the origin of some taxa. Nuttall's sensitive briar appears native to Central Illinois based on the dates of collection, habitat, and location (Webb 1985; Fertig 2011). The Kane County population may have been native based on the habitat, associated plants, and the distance from potential sources of introduction, such as railroads. Populations in Bureau, DuPage and Winnebago counties are presumed to be adventive due to their association with other western plants and site history, including railroads, stockyards, and use as a horse and mule training facility. This taxon was likely never common in Illinois, and naturally occurring populations may have been lost to agriculture or woody invasion. Its sprawling growth habit also makes it difficult to locate when not in bloom. Future field searches may identify additional populations that will further clarify the natural distribution of this species in Illinois.

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APPENDIX

Herbarium records for *Mimosa quadrivalvis* L. var. *nuttallii* (DC.) Barneby (Nuttall's sensitive briar, Fabaceae) in Illinois.

BUREAU COUNTY: Railroad right-of-way at Route 88, 4.0 km east of Sheffield, 17 September 1965, A. C. Koelling 5527 (ISM).

DUPAGE COUNTY: **West Chicago Prairie**, plants growing with *Eryngium yuccifolium* Michx., *Euphorbia corollata* L., *Ratibida pinnata* (Vent.) Barnh., *Poa compressa* L., and *Cornus racemosa* Lam., W. Lampa and A. Able s. n., 17 August 1984 (MOR). **West Chicago Prairie**, ten plants growing with *Baptisia australis* (L.) R. Br., *Carex bushii* Mack., *Coreopsis tripteris* L., *Desmodium canadense* (L.) DC., *Eryngium yuccifolium* Michx., and *Sorghastrum nutans* (L.) Nash., 3 July 2019, S. N. Kobal and W. Lampa s.n. (EIU, MOR).

FAYETTE COUNTY: **Horn Prairie Grove Land and Water Reserve,** gravelly, dry prairie remnant. A single plant growing with *Euphorbia corollata* L, *Schizachyrium scoparium* (Michx.) Nash, *Helianthus occidentalis* Riddell, and *Dalea purpurea* Vent., 8 June 2019, W. McClain 3730 (EIU).

KANE COUNTY: **Fellowship Deaconry**, Elburn. Six plants in hill prairie remnant with *Dalea purpurea* Vent., *Euphorbia corollata* L, *Schizachyrium scoparium* (Michx.) Nash, 5 July 1970 H. Eilers s. n. (MOR).

MORGAN COUNTY: **Sandy loess bluff**, R. T. Rexroat 10532, 10557, 25 September 1967 (ISM); sandy loess bluff, 29 September 1968, R. T. Rexroat 10657, 10658 (ISM); sandy loess bluff, R. T. Rexroat 16541, 16542, 16543, 16559 (ISM).

PEORIA COUNTY: **Horseshoe Bottoms Overlook**, gravelly slope, Peoria, June 1900, F. E. McDonald s. n. (ILL); dry sandy soil, Peoria, August 1901; F. E. McDonald s. n. (ILL); Jun. 1915, No collector or habitat listed, (KNOX); dry hillside, out 7^{th} Street beyond Western Ave., Peoria, 7 June 1921, V. H. Chase 3372 (ILL).

WINNEBAGO COUNTY: **Bell Bowl Prairie**, gravel bluff, 8 km south of Rockford, Greater Rockford Airport, 23 June 1958, E. W. Fell 58-237 (ISM).

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Pollinator Surveys at Illinois Nature Preserve Sites in West-Central Illinois

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Abstract: From 2018-2020 insect pollinators and their plant associations were surveyed on 18 protected prairie, wetland, and forest natural areas in west-central Illinois with the use of photographic documentation. The goals of the survey were to establish baseline taxonomic lists of potential pollinators, determine floral associations, assess the impacts of invasive species, find specialist pollinators associated with rare community types, evaluate insect preference for high-quality remnants, and obtain new ideas to guide management for the benefit of the pollinating insect community. Six sites were sampled each year, with the goal of surveying each site on a five-year rotation. Each site was surveyed every 1-2 months (April – September), for 60-80 minutes per visit following pre-established meandering transects. Personal experience was used to identify plant and many insect species. Photographs for most taxa (over 90%) were submitted to the websites BugGuide.net and I-Naturalist.org for documentation and to provide additional assistance for identification of insects. Potential pollinators and their floral associations were recorded to species level when possible. Three years of surveys (18 sites) have identified about 673 potential pollinators on 209 species of plants. Taxonomic richness was similarly high (20-22%) for flies, bees, and beetles, followed by wasps (16%). Bees had the highest abundance followed by beetles, flies, and butterflies. There was little difference in the richness and abundance of insects on sites receiving moderate-to-low intensity management and those which received no management. The replication of these surveys every five years will be important to note changes in the communities of pollinators and the impacts of management.

Introduction

Little data exists statewide on insect pollinators and their floral associations, especially for taxa other than bees. Goals of the Illinois Wildlife Action Plan (Illinois Department of Natural Resources, IDNR 2005) call for the collection of more data on pollinators in Illinois for the purpose of improving pollinator-friendly land management. Photo pollinator surveys were established in west-central Illinois to contribute towards these goals. The study was designed to focus on six key points: 1) diversity and abundance of insect pollinators; 2) floral associations; 3) impact of invasive species; 4) insect diversity within natural community types; 5) insect preference for high-quality remnants versus lower quality degraded sites; and 6) effects of management on insect diversity and abundance.

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Methods

From 2018 to 2020 a repeatable pollinator monitoring program was established in west-central Illinois natural areas. Each year six sites were selected with the goal of revisiting sites on a five-year rotation (Table 1). All sites chosen were larger than 10 acres and permanently protected by the Illinois Nature Preserves Commission (INPC), either as dedicated nature preserves (NP) or registered land and water reserves (LWR). To increase efficiency and reduce travel time, surveys were conducted in pairs, sampling two sites/day. Most sites are owned and managed by the IDNR; others are owned by private individuals, municipalities, or land trusts.

To establish survey methods the US Fish & Wildlife Service (FWS) Bombus Survey procedures were reviewed (https://www.fws.gov/midwest/endangered/insects/rpbb/pdf/Bumble_ Bee Survey Field Data Sheet April2019.pdf). The FWS methods focus on catch and release with photos taken of all *Bombus* species (bumble bees) along with recording the abundance of domesticated honeybees (*Apis mellifera*). The survey also provides for recording management practices and any stressors or threats. The

Table 1: Schedule of pollinator survey sites visited (years 1-3) or with planned visits (years 4-5) in west-central and central Illinois nature preserves and land and water reserves.

	County	Site Names
Year 1	Hancock	Mississippi River Sand Hills NP, Samuel Barnum Mead Savanna NP, Cecil White Prairie LWR
	Fulton	Harper-Rector Woods NP
	McDonough	Short Fork Seep NP
	Rock Island	Josua Lindahl Hill Prairie NP
Year 2	Adams	Allendale Springs LWR
	Hancock	Stony Hills NP
	Henderson	Ellison Creek Sand Prairie NP
	Knox	Haw Creek Sedge Meadow LWR
	Peoria	Jubilee College Forest NP
	Schuyler	Williams Creek Bluff LWR
Year 3	Adams	Fall Creek Gorge LWR, Burton Cave NP
	Adams/Brown	Robert A. Evers LWR
	Peoria	Singing Woods NP, Robinson Park Hill Prairies NP
	Pike	Grubb Hollow Hill Prairie NP
Year 4	Cass	Cox Creek Hill Prairies LWR
	Hancock	Cedar Glen NP
	Knox	Forever Fields LWR
	McDonough	Argyle Hollow Barrens NP
	Morgan	Meredosia Hill Prairie NP
	Stark	Harper's Woods NP
Year 5	Hancock	Crystal Glen LWR
	Henderson	Harry N. Patterson Savanna LWR
	Fulton	Kedzior Woodlands LWR
	Mason	Sand Prairie Scrub Oak NP, Long Branch Sand Prairie NP
	Rock Island	Black Hawk Forest NP

Xerces Society's Upper Midwest Pollinator Survey (https://www.xerces.org/publications/id-monitoring/upper-midwest-citizen-scientist-pollinator-monitoring-guide-native) also was consulted. Both surveys involve recording specifics on observers, location, date, time, duration, cloud cover, temperature, wind speed, habitat type, and floral species. The Xerces survey has participants record bees, either based on type assigned by size, color and notable features or genus, as well as non-bees (birds, spiders, and other insect groups). Data collection methods for both surveys were adopted along with the addition of photographing and recording all potential pollinator insects and floral associations to species level when possible.

Individual site survey visits were made four times during the year (April/May, June, July, and Aug/Sept) to account for phenological variation and to capture the most species diversity. Survey duration ranged between 60-90 minutes during each site visit. Counts were conducted between late morning and early afternoon (generally 10am – 3pm) and, when possible, under favorable conditions: above 70°F, little to no winds, sunny skies. On a few occasions the temperatures were around 60°F. At times winds were gusting to 20 mph when insect pollinators were present, challenging photo documentation.

Insect Diversity and Abundance

All bees, butterflies, and skippers were recorded regardless of whether they were visiting flowers at the time of observation. Flower-visiting wasps, beetles, flies, moths, true bugs, along with a few other insect groups were recorded if observed with pollen; also recorded were insects determined to be closely associated with pollen and nectar feeding or gathering based on previous experience and photo observations (Figure 1). Flower-visiting insect numbers were recorded along with their plant associations. Extensive personal experience and training facilitated recognition of insect groups

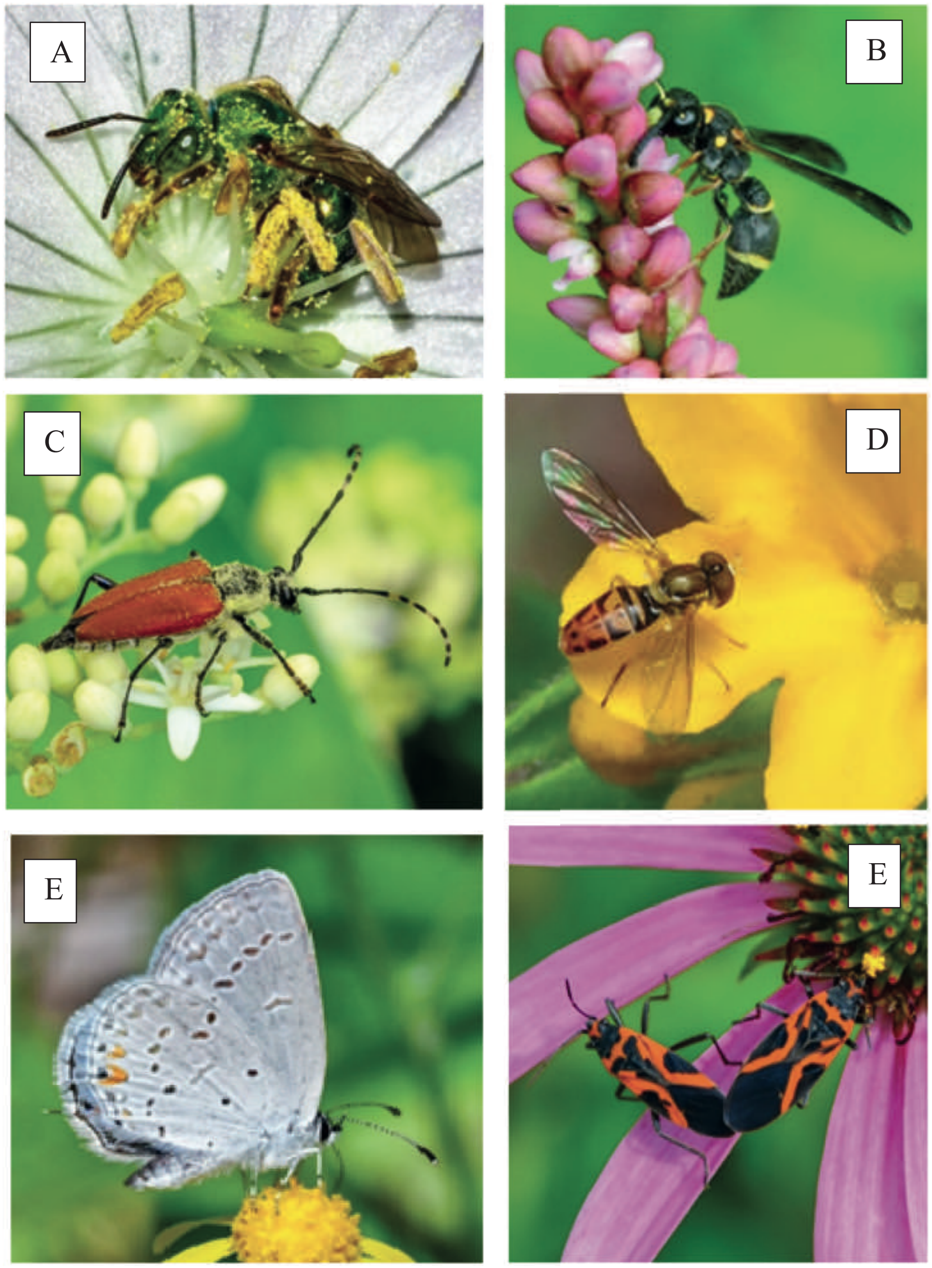

Figure 1. Photos of different types of pollinators surveyed: A) green sweat bee (*Agapostemon* sp.) on wild geranium (*Geranium maculatum*); B) mason wasp (*Anacistricerus* sp.) on smartweed (*Persicaria* sp.); C) red flower longhorn beetle (*Brachyleptura rubrica*) on dogwood (*Cornus* sp.); D) margined calligrapher fly (*Toxomerus marginatus*) on hoary puccoon (*Lithospermum canescens*); E) eastern tailed blue (*Cupido comyntas*) on prairie ragwort (*Packera plattensis*); F) false milkweed bug *(Lygaeus turcicus*) on pale purple coneflower (*Echinacea pallida*).

and behavior. Guides consulted to assist with identification included Eaton and Kaufman (2006), Skevington et al. (2019), and Holm (2014, 2017, 2021).

A Nikon D500 camera with a Tameron 90mmVR macro lens was used to photograph as many pollinators as possible. Most of the photographs were uploaded to the following websites for additional documentation and identification help/confirmation: BugGuide (https://bugguide.net) and I-Naturalist (https://www.inaturalist.org). Specimens of a few dozen bees were hand-collected in 2019 and 2020 and sent to Laura Rericha-Anchor (Cook County Forest Preserve District) for lab identification. These will be curated at the Field Museum. Attempts were made to photograph bees prior to collection to later match lab identifications with photographs.

Floral Associations

Meandering transects routes were mapped through different community types utilizing constructed lanes and trails, deer trails, creek beds and areas of less dense brush for ease of traversing the landscape. Botanical nomenclature follows Mohlenbrock (2014). Most plants were identified to species with the exception of a few genera: *Desmodium* (tick trefoils), *Erigeron* (fleabanes), and *Pycnanthemum* (mountain mints). Flowering plants with insect visitors observed during the survey were recorded for the site and assigned to each insect associated with the flowers.

Invasive Species

Information on invasive species, both flora and fauna, was collected along with the insect and plant data. Special attention was given to documenting the number of domesticated honeybees (*Apis mellifera*) on each site including observations of feral hives within the sites and any manufactured hives nearby.

Natural Community Types, Quality and Management

Survey routes were designed to include high-quality remnants, when present, as well as other community types with an emphasis on high-density patches of flora resources. Information on community types and grades (quality assessments) found on each site was obtained from the Illinois Natural Areas Inventory (INAI) database (IDNR 2021). The community type where each insect was found was also recorded.

To compare natural community types the 18 sites were divided into four groups: hill prairies, forests, grasslands or prairie, and wetlands. While these terms loosely describe the primary natural or remnant community, each site also included other buffer communities, generally forest or grassland patches. Thirteen of the sites surveyed are recognized on the INAI as Category I sites (high-quality remnant communities). The remaining five sites are Category II INAI sites (habitat for state endangered or threatened species).

Sites were divided into three groups based on the extent of management: 1) high intensity management - sites with at least two hot fires and brush clearing within the past five years; 2) moderate-to-low intensity management - sites which had moderate to cool burns and some brush control within the past 10 years; and 3) sites which have received no management in the past 20 years. Information on the frequency and effectiveness of management practices, primarily prescribed fire and brush clearing, was collected during routine surveillance by INPC staff and from IDNR District Heritage Biologists in charge of management on state-owned sites.

Table 2: Insect species richness and abundance for pollinator survey conducted from 2018 to 2020 (years 1-3) on nature preserves and land and water reserves in west-central Illinois.

Year	Total Taxa	New Taxa	Number of Individuals
2018	413	413	4,418
2019	401	137	3,986
2020	370	123	3,423
TOTAL		**673**	**11,827**

RESULTS

Insect Diversity and Abundance

The total number of insect taxa documented for all three years combined is 673 (Table 2). Ideally, all observations would be made to species level; however, due to limitations with identification using photographs, only 393 have been identified to species, with the remainder assigned to subgenus, genus, tribe, subfamily, family or higher taxonomic ranks. As additional identifications are provided from photographs uploaded to BugGuide.net and I-Naturalist.com this information will be updated. Attempts were made to record descriptions for those taxa likely to have multiple species per subgenus, genus, tribe, etc., especially mining bees (*Andrena* spp.) which are single-brooded and often specialize in one plant genus or family. Only butterflies and skippers were all identified to species level.

Much effort was taken to be conservative in recording the total number of taxa, with the goal of attempting to represent total species. However, it is possible that some difficult to distinguish groups may be over or under-represented. For example, determinations of individual bee taxa could be slightly inflated by recognizing multiple taxa at the genus or higher taxonomic rank. However, it should be noted that bees within the genus *Lasioglossum* subgenus *Dialictus* (metallic sweat bees) are particularly diverse, comprising a dozen or more species. Some other difficult groups such as tachinid flies (Tachinidae) and muscid flies (Muscidae), by possibly not recognizing all individual taxa, may be under-counted.

Along with challenges related to taxonomic assignment is the determination as to whether the insect is

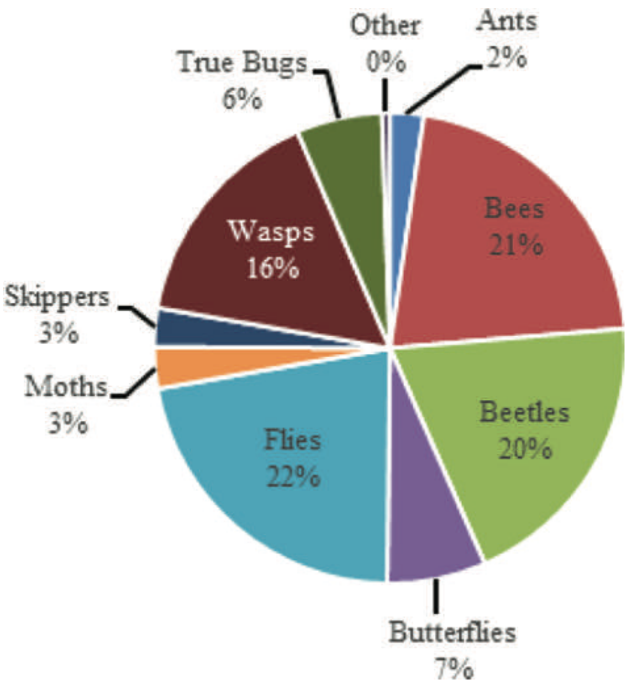

Figure 2. Taxonomic richness (rounded percentage of the number of taxa) of pollinators recorded at west-central Illinois nature preserves and land and water reserves for 2018-2020 combined (0% = < 0.5%).

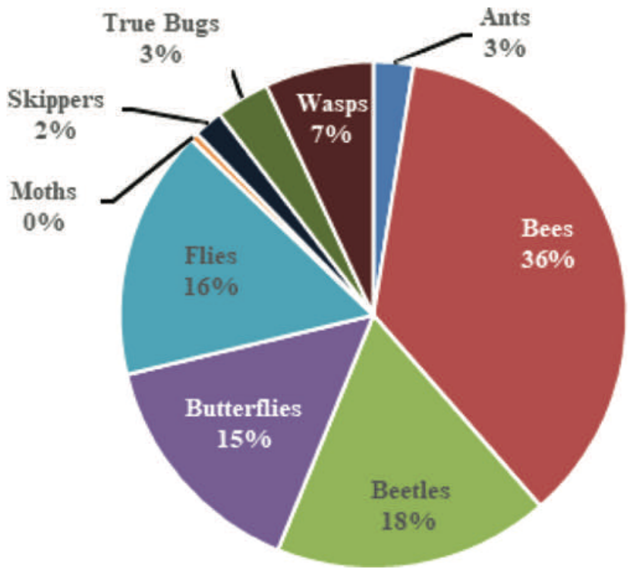

Figure 3. Taxonomic abundance (rounded percentage of the number of individuals) of pollinators recorded at west-central Illinois nature preserves and land and water reserves for 2018-2020 combined (0% = < 0.5%).

associated with pollination. Most observations were made of insects actually feeding on pollen or nectar of flowers; however, there are times when insects that feed on floral resources were involved in other activities, primarily resting or predatory/scavenger feeding behaviors for those with multiple dietary needs. Decisions on what taxa to count were also made based on previous observations of these insects feeding on flora resources or those coated with pollen.

Based on the number of different taxa for each taxonomic group for all three years combined (Figure 2), flies, bees, and beetles each made up about one-fifth of the total (20-22%) with wasp diversity also high (16%). Taxonomic richness ranged from a high of 175 taxa at both Mead Savanna and Short Fork Seep in 2018 to a low of 115 taxa at Ellison Creek Sand Prairie NP 2019. The total number of taxa recorded in 2018 and 2019 was similar; total taxa counts were lower in 2020 (Table 2).

Insect taxa numbers and total abundance recorded each year are shown in Table 2. In all three years, bees made up the majority of the total individuals observed throughout the year (Figure 3). Total abundance of butterflies, compared to other groups, was relatively high considering the low level of observed taxonomic richness, due to a few taxa found in large numbers. The opposite was true for wasps where, in most cases, only 1-3 individuals of each taxa were observed.

Floral Associations

Plant preference (foraging visitations) by insects was assessed for combined 2018-2020 surveys (Table 3). Potential pollinating insects were documented on over 209 plant species. The top 20 plants preferred by the largest number of pollinating insect species belong to nine different families highlighting the importance for plant species diversity. Three of the top-20 ranking plant species were goldenrods (*Solidago* spp.). Some of the plants visited by the most species of insects, including invasive species, were weedy and abundant at the sites visited.

Invasive Species

A quarter of the top 20 plants visited by the largest number of insect species were non-native plants: *Pastinaca sativa* (wild parsnip), *Alliaria petiolata* (garlic mustard), *Taraxacum officinale* (dandelion), *Daucus carota* (Queen Anne's lace), and *Barbarea vulgaris* (yellow rocket). All of these belong to families also represented by native species familiar to native insect pollinators. These non-native flowers all bloom during the spring and early summer. By mid-to-late summer ample natives such as *Solidago* (goldenrods) and

Table 3: Plants ranked by diversity of insect visitors to nature preserves and land and water reserves in west-central Illinois. * = non-native taxa.

Rank	Scientific Name	Common Name	# Insect Spp.
1	*Solidago canadensis*	Canada goldenrod	113
2	*Pastinaca sativa**	wild parsnip	96
3	*Erigeron annuus/strigosus*	daisy fleabane	84
4	*Ageratina altissima*	white snakeroot	81
5	*Cryptotaenia canadensis*	honewort	68
6	*Pycnanthemum* spp.	mountain mints	59
7	*Alliaria petiolata**	garlic mustard	49
8	*Monarda fistulosa*	wild bergamot	47
9	*Amorpha canescens*	leadplant	46
10	*Asclepias syriaca*	common milkweed	46
11	*Solidago ulmifolia*	elm-leaved goldenrod	45
12	*Claytonia virginica*	spring beauty	40
13	*Taraxacum officinale**	dandelion	40
14	*Cornus drummondii*	rough-leaved dogwood	38
15	*Daucus carota**	Queen Anne's lace	37
16	*Apocynum cannabinum*	Indian hemp	35
17	*Liatris aspera*	rough blazingstar	35
18	*Solidago nemoralis*	old field goldenrod	35
19	*Barbarea vulgaris**	yellow rocket	33
20	*Campanulastrum americanum*	American bellflower	33

Symphyotrichum (asters) reduce pollinators' reliance on non-native plants.

Natural Community Types and Quality

All survey sites included multiple vegetative communities in additon to the primary community (Table 4). While data were recorded on the community type where each insect was found, insects are mobile and most were not restricted to a particular community type. While wetlands constituted a small samples size (11% of all sites), they did have a greater taxonomic richness and abundance than other community types. There are no notable differences in taxonomic richness and abundance between high-quality remnants and more degraded sites (Table 5).

Management

Abundance may be greater, especially for bees, beetles, and butterflies, on the sites that were intensely managed (Table 6). The number of intensively managed sites surveyed is low and more data collection is needed to determine if the differences are significant. From data so far collected, little difference is evident between sites which had received moderate-to-low intensity management and sites that had not been managed.

DISCUSSION

Insect Diversity and Abundance

The decision to use photography and personal observations rather than specimen collection as the chief means to document insect pollinators was made due to lack of resources (time and ability to process killed specimens) as well as a general need to demonstrate that non-lethal methods of pollinator data collection can be used to reduce the impact to native insects (some of which may be declining) on our protected natural areas. The use of photography as an effective means of data collection for pollinator-plant associations is supported by Ward *et al.* (2014) who found that two site visits per year at a minimum of 15 minutes each could provide a reliable estimate of bee diversity and abundance comparable to lethal methods (bowls and netting). Droege *et al.* (2016) and Connor *et al.* (2019) concur with the usefulness of photography and stress the importance of the taxonomic expertise of the observer/photographer in effectively using photography for data collection of bees and other flower-visiting insects.

Floral Associations and Invasive Species

Efforts to increase the availability of native floral resources for pollinators largely involves planting former

Table 4: Comparison of natural community types for nature preserves and land and water reserves in west-central Illinois.

Site name	Year	Primary natural community	Natural quality	Management	Time	Total taxa	taxa/hr	Total ind.	Ind/hr
Cecil White Prairie	2018	loess hill prairie	Cat. 1 Grade B	high	4.3	138	32.1	694	134
Josua Lindahl Hill Prairie	2018	loess hill prairie	Cat. 1 Grade B	mod/low	5.2	139	26.7	727	140
Grubb Hollow Hill Prairie	2020	loess hill prairie	Cat. 1 Grade B	mod/low	4.6	122	26.5	618	134
Singing Woods	2020	loess hill prairie	Cat. 1 Grade B	mod/low	4.6	117	25.4	437	95
Robinson Park Hill Prairies	2020	loess hill prairie	Cat. 1 Grade B	mod/low	4.8	124	25.8	617	121
Mississippi River Sand Hills	2018	sand hill prairie	Cat. 1 Grade B	mod/low	4.7	148	31.5	445	75
Harper-Rector Woods	2018	forest	Cat. 1 Grade B	none	4.6	135	29.3	643	140
Allendale Spring	2019	forest	Cat. 2 E/T spp.	none	4.8	163	34.0	733	153
Jubilee College Forest	2019	forest	Cat. 1 Grade B	none	4.6	158	34.3	665	145
Williams Creek Bluff	2019	forest	Cat. 1 Grade B	mod/low	6.0	141	23.5	615	103
Fall Creek Gorge	2020	forest	Cat. 2 E/T spp.	none	4.7	120	25.5	589	125
Burton Cave	2020	forest	Cat. 2 E/T spp.	none	4.3	131	30.5	440	102
Robert A. Evers	2020	woodland	Cat. 1 Grade B	high	5.0	159	31.8	722	144
Mead Savanna	2018	prairie	Cat. 1 Grade B	high	4.8	175	36.5	1077	224
Ellison Creek	2019	sand prairie	Cat. 2 E/T spp.	none	4,0	115	28.8	627	157
Stony Hills	2019	prairie restoration	Cat. 2 E/T spp.	mod/low	4.3	155	36.0	531	123
Short Fork Seep	2018	wetland	Cat. 1 Grade B	none	4.1	175	42.7	814	199
Haw Creek Sedge Meadow	2019	wetland	Cat. 1 Grade C	mod/low	4.6	141	30.7	800	174

crop fields and degraded areas with native vegetation (Vaughan *et al.* 2014). For remnant areas increasing pollen and nectar availability focuses on management: brush clearing and prescribed fire to reduce shade and promote more flowering, and control of invasive plants. Stubbs *et al.* (2007) and Kaiser-Bunbury *et al.* (2017) show that non-native plants are detrimental and efforts to control them and restore diverse native vegetation improves pollinator communities.

West-central Illinois is known for very high deer densities, compared to the rest of the state, and many of the early spring forest ephemerals have been lost due to extensive deer browse and other habitat degradation such that many insect pollinators are reliant upon

Table 5: Comparison of natural community quality for nature preserves and land and water reserves in west-central Illinois. * Denotes higher quality (Illinois Natural Areas Inventory, Category I) versus lower quality communities (Category II) supporting state endangered or threatened species.

Site name	Natural community	Natural quality*	Time (hrs.)	Total taxa	taxa/hr	Total ind.	Ind/hr
Cecil White Prairie	loess hill prairie	Cat. 1 Grade B	4.3	138	32.1	694	134
Josua Lindahl Hill Prairie	loess hill prairie	Cat. 1 Grade B	5.2	139	26.7	727	140
Grubb Hollow Hill Prairie	loess hill prairie	Cat. 1 Grade B	4.6	122	26.5	618	134
Singing Woods	loess hill prairie	Cat. 1 Grade B	4.6	117	25.4	437	95
Robinson Park Hill Prairies	loess hill prairie	Cat. 1 Grade B	4.8	124	25.8	617	121
Mississippi River Sand Hills	sand hill prairie	Cat. 1 Grade B	4.7	148	31.5	445	75
Mead Savanna	prairie	Cat. 1 Grade B	4.8	175	25.5	1077	224
Harper-Rector Woods	forest	Cat. 1 Grade B	4.6	135	29.3	643	140
Jubilee College Forest	forest	Cat. 1 Grade B	4.6	158	34.3	665	145
Williams Creek Bluff	forest	Cat. 1 Grade B	6.0	141	23.5	615	103
Robert A. Evers	woodland	Cat. 1 Grade B	5.0	159	31.8	722	144
Short Fork Seep	wetland	Cat. 1 Grade B	4.1	175	36.0	814	199
Haw Creek Sedge Meadow	wetland	Cat. 1 Grade C	4.6	141	30.7	800	174
Allendale Spring	forest	Cat. 2 E/T spp.	4.8	163	34.0	733	153
Fall Creek Gorge	forest	Cat. 2 E/T spp.	4.7	120	25.5	589	125
Burton Cave	forest	Cat. 2 E/T spp.	4.3	131	30.5	440	102
Ellison Creek	sand prairie	Cat. 2 E/T spp.	4.0	115	28.8	627	157
Stony Hills	prairie restoration	Cat. 2 E/T spp.	4.3	155	36.0	531	123

non-native plants during the spring and early summer. Native species that flower after many non-native species (e.g., *Solidago* and *Symphyotrichum*), may have not been as impacted by habitat degradation. Many of the plant associations documented were of the most abundant species found at the INPC survey sites in west-central Illinois and may not necessarily reflect preferences in other areas of the state. As pollinator-favored non-natives such as *Pastinaca sativa*, *Daucus carota*, *Alliaria petiolata*, *Melilotus* spp. (yellow and white sweet clovers), and *Elaeagnus umbellata* (autumn olive) are reduced and eliminated at managed sites, replacing them with native plants from the same family and/or with similar flowering times is critical to sustain pollinator communities.

Honeybees were seen on all but two of the survey sites. However, honeybee abundance does not currently appear to have an impact on the native bees and other

Table 6: Comparison of management intensity of nature preserves and land and water reserves in west-central Illinois. * high = high-intensity management: brush clearing; and at least 2 hot prescribed burns within past 5 years; mod/low = moderate to low intensity management: some brush clearing and/or 1 to 2 moderate-to-cool prescribed burns within past 5 years; none = no management conducted within past 10+ years.

Site name	Management*	Time (hrs.)	Total taxa	taxa/hr.	Total ind.	Ind/hr.
Cecil White Prairie	high	4.3	138	32.1	694	134
Robert A. Evers	high	5.0	159	31.8	722	144
Mead Savanna	high	4.8	175	36.8	1077	224
Josua Lindahl Hill Prairie	mod/low	5.2	139	26.7	727	140
Grubb Hollow Hill Prairie	mod/low	4.6	122	26.5	618	134
Singing Woods	mod/low	4.6	117	25.4	437	95
Robinson Park Hill Prairies	mod/low	4.8	124	25.8	617	121
Mississippi River Sand Hills	mod/low	4.7	148	31.5	445	75
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Stony Hills	mod/low	4.3	155	36.0	531	123
Haw Creek Sedge Meadow	mod/low	4.6	141	30.7	800	174
Harper-Rector Woods	none	4.6	135	29.3	643	140
Allendale Spring	none	4.8	163	34.0	733	153
Jubilee College Forest	none	4.6	158	34.3	665	145
Ellison Creek	none	4.0	115	28.8	627	157
Fall Creek Gorge	none	4.7	120	25.5	589	125
Burton Cave	none	4.3	131	30.5	440	102
Short Fork Seep	none	4.1	175	42.7	814	199

insect pollinators in most, if not all, of the INPC sites in west-central Illinois. While there is concern about the impacts of domesticated honeybees, the surveys thus far have revealed that this invasive species represents, on average, less than 5% of the total bee population overall. At a few sites, with known or likely feral hives within the site, honeybees represented up to 15-20% of bees. These included Stony Hills in 2019 and Burton Cave in 2020. Currently, the primary concern related to honeybees in this area is their preference for pollinating non-native invasive species which can contribute to the spread of these plants through increased seed production.

Natural Community Types and Quality

Much work has been done in Illinois to determine quality assessments of sites based on the conservatism of insects. This work was largely initiated by Panzer *et al*. (1995) and later followed by Wallner *et al*. (2012) and Heads *et al*. (2017). Work done by Ron Panzer and associates focused primarily on insects found in remnant prairies: Lepidoptera (butterflies and moths), Orthoptera (grasshoppers, walking sticks, katydids), Thysanoptera (thrips), Hemiptera (stinkbugs, leafhoppers, treehoppers, planthoppers), Coleoptera (carrion beetles), and *Bombus* (bumble bees). Adam Wallner and Chris Dietrich began the monumental task of assigning quality assessment values to Auchenorrhynca (leafhoppers, treehoppers, planthoppers, and cicadas). More recently Michael Jeffords and Susan Post created methods to assigned quality assessment values to butterflies in the state (Heads *et al*. 2017). This study seeks to contribute field observations toward these efforts.

There remains a critical need to collect more insect data since these insects play a critical role in the management of natural plant communities through pollination. While it is unclear how many flower-associated insects have been lost, finding 673 taxa over a period of three years indicates that a high taxonomic richness remains in west-central Illinois. It also appears evident that protected INPC sites are essential to insect diversity. More data are needed to determine whether there is a statistical difference in the taxonomic richness and abundance of high-quality remnants (INAI Category I) and more degraded (e.g., Category II and other) sites.

Management

To collect additional data to test the impacts of management, four more intensively managed sites will be added to the study over the next two years. Additionally, a few of the sites surveyed during the first round are undergoing increased management and may rate as high intensity management during the next replication of surveys. Several of the sites within this project: Robert A. Evers, Meredosia Hill Prairie, Grubb Hollow Hill Prairie, and Robinson Park Hill Prairie are also being monitored by the Illinois Natural History Survey (INHS) as part of an Insect State Wildlife Grant (SWG, initiated in 2020) which is attempting to collect data on rare, state-listed, and SGNC leafhoppers, butterflies and skippers. Collection of pollinator data will complement the Insect SWG project.

The benefits of forest management for insect diversity are supported by Hanula *et al*. (2015) who show that tree thinning, and gap creation, prescribed fire, and invasive plant control are beneficial to pollinators within forest communities. Reduction in canopy cover allows for more sunlight penetration which improves conditions for more flowering plants and thus more pollen and nectar availability (Peterson and Reich 2008).

Prescribed fire strategies within burn units call for unburned refugia to be left. In all cases patches of unburned areas remain and fire is not forced into these patches. Also, managed sites undergoing aggressive forest/tree-thinning management all have ample refugia adjacent to these preserve/reserves which allows those species which may be lost to intense fire (e.g., those that overwinter above ground) to readily return to the landscape.

Conclusions

This pollinator study was designed to collect data on a wide variety of flower associated insects and the factors that may be influencing their populations. Initial consideration was given to factors such as flora composition, vegetative community types, and the impacts of invasive flora and fauna, and management intensity and frequency. There are other factors, some yet to be realized, that may provide for useful analysis when comparing pollinating insect communities.

This study is still in the first baseline collection phase with two more years to go before the surveys are replicated at these sites to note any changes after five years. Additional comparisons will be made for sites in close proximity, those within travel distance of insect pollinators. More data are needed to better determine taxonomic composition of remnants and various vegetative community types, and to assess the impacts of management more comprehensively. Land cover changes to the surrounding landscape will likely be minimal after five years, while some study sites are undergoing an increased frequency and intensity of management. There may be changes over time in the insect community for these sites versus those receiving little or no management. Questions remain regarding the optimal size and location of refugia in relation to the size and percentage of area burned, cleared, or sprayed. Answering these questions will be beneficial to the evaluation of management techniques.

Other factors to consider over time that may have impacts on the pollinator communities include temporal changes in plant communities, competition with domesticated honey bees, potential impacts of non-native insects introduced for biocontrol, increased external pressures such as agricultural pesticide usage, additional loss of habitat within the areas surrounding the protected study sites, and impacts of climate change on phenology and shifts in species range.

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Insect Visitors of *Phemeranthus calycinus* (Raf.) Kiger (Montiaceae, Large-Flowered Rockpink) in Illinois

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Abstract: Thirty-nine insect visitors were collected from blossoms of large-flowered rockpink (*Phemeranthus calycinus* (Raf.) Kiger Montiaceae), representing three orders, thirteen genera, and eighteen species. Native solitary bees of the genera *Adrena, Augochlorella, Calliopsis, Ceratina*, *Halictus, Lasioglossum*, *Megachile, Melissodes*, and *Pseudopanurgus* were the most frequent visitors, followed by the hoverflies *Hemipenthes sinuosa* and *Allograpta obliqua*. Butterflies, *Asterocampus celtis* and *Nathalis iole*, were rare visitors to rockpink flowers. Early afternoon flowering coincided with peak insect activity, and flower numbers were greatest during June. All insects identified in this study were generalists known to gather pollen from several unrelated plant species. Maintaining a sparsely vegetated outcrop appears essential for high flower visibility to foraging insects, and rockpink/insect visitor interactions.

Introduction

The plant genus *Phemeranthus* (Raf.) Kiger (rockpink, Montiaceae) is represented by 16 species in the Flora of North America, including three taxa native to Illinois (Gleason and Cronquist 1991; Kiger 2003; Mohlenbrock 2014). *Phemeranthus parviflorus* (Nutt.) Kiger (small-flowered rockpink), present in four southern counties, is state endangered; *Phemeranthus rugospermus* (Holz.) Kiger (wrinkle-seeded rockpink), currently unlisted, has a scattered distribution in 12 northern counties; and *Phemeranthus calycinus* (Engelm.) Kiger (large-flowered rockpink), currently known only from Monroe County in southwestern Illinois, is state endangered (Illinois Endangered Species Protection Board 2020; Mohlenbrock 2014).

Large-flowered rockpink ranges west from Illinois into Colorado and New Mexico and south from Nebraska to Texas and Louisiana (Kiger 2003). This herbaceous perennial, up to 40 cm tall, characteristically has rhizomatous, semi-woody roots; fleshy ascending stems that become decumbent and branched with age and size; sessile, fleshy, subterete, linear leaves up to 7 cm long; cymose inflorescences on a scape-like peduncle up to 25 cm tall that greatly overtops the leaves; 2 persistent ovate to suborbicular sepals, 4-6 mm long; five (rarely four) pink to red-purple obovate petals,10-15 mm long (Figure 1); 25-45 stamens; stigma 1, 3-lobed, subcapitate; capsules broadly ovoid, 6-7 mm long; and 1 mm long, black seeds that lack ridges (Kiger 2003).

This rockpink is an indicator species of the Central Section of the Illinois Ozark Natural Division of southwestern Illinois (Schwegman *et al*. 1973). Dr. R. H. Mohlenbrock first discovered this plant in 1954 on sandstone ledges in Randolph County at a site known as Castle Rock (Jones and Fuller 1955; Mohlenbrock 2014). This population, at that time, consisted of hundreds of plants, but competition from woody and herbaceous species along with the lack of management caused its recent disappearance (Newman *et al*. 2019).

Rockpinks are well known for the very brief blooming of individual flowers of just a few hours. The blooming times for *Phemeranthus* vary by species and populations, and observations indicate that flowering may also be influenced by local weather, such as cloud cover and the amount of direct sunlight (Price 2012; and this study). Large-flowered rockpink blossoms in Monroe County have been observed to open from 12:30 to 1:30 in the early afternoon and permanently close from 4:00 to 5:00 P.M. throughout a nearly three-month flowering period. The lower flower buds on the peduncle develop first, and fertilized blossoms produce capsules that mature quickly and begin releasing tiny, black seeds while blooming continues on the upper peduncle. Many of these seeds fall into moss and lichen colonies, present in shallow depressions, which appear to serve as germination beds based on the numerous seedlings observed among these plants each year of the study.

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Figure 1. The bee *Augochlorella aurata* Smith visiting a *Phemeranthus calycinus* blossom. Note the wiry peduncle, five petals, and number of stamens (approximately 45).

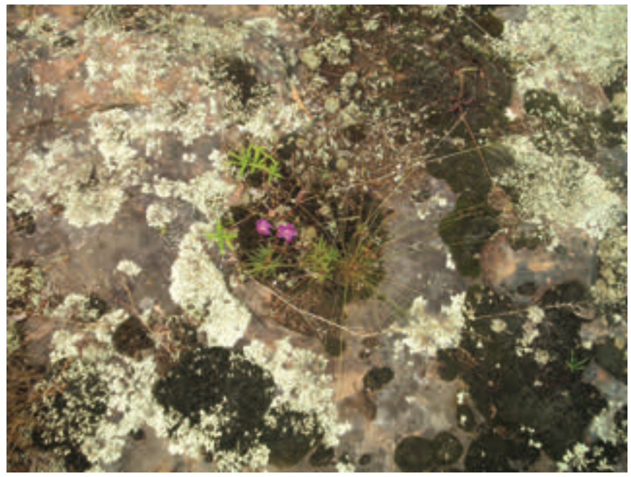

Figure 2. Two *Phemeranthus calycinus* plants in center of photograph showing flowers, stems and fleshy, terete leaves. Note their presence in a moss colony.

Little data are available concerning the insect visitors of the plant genus *Phemeranthus*. The bee *Calliopsis andrenoformis* Smith is known to visit flowers of the wrinkle-seeded rockpink, *P. rugospermus* (Price 2012). Bees of the genera *Apis, Auglochlora*, *Bombus,* and *Lasioglossum* have been documented to visit flowers of the rockpinks *P. mengesii* (W. Wolf) Kiger and *P. teretifolius* (Pursh) Rafinesque in the piedmont of Georgia. Sweat bees (Halictidae) were the primary pollinators of P. *mengesii* and *P. teretifolius*, and they are the only insects currently known to visit flowers of *P. calycinus* (Price 2012). No insects are known to be entirely dependent on any rockpink species.

No data are available for insect visitors to the three rockpink species native to Illinois. Such data would be useful in determining management for the rock outcrop community that supports this plant in Monroe County. The purpose of this study was to document insect visitors of large-flowered rockpink in Illinois, to describe the interactions of these visitors with this rare plant, to discuss the ecology of this outcrop community, and to propose future maintenance of this site and other rock outcrop communities.

METHODS

Study site

The Monroe County rockpinks are present on a nearly level outcrop of Aux Vase sandstone, 35 m × 85 m, situated on the north bank of a tributary to Horse Creek (Grimley and Shofner 2008; McClain 2009). This expanse of sandstone is characterized by numerous shallow basins, ranging in depth from one to two cm, which vary in width from a few centimeters to nearly one meter. These basins hold water temporarily following rain, and many contain thin layers of soil sufficient to support colonies of mosses and lichens. Rockpinks, ranging from seedlings to mature plants, are concentrated in these colonies (Figure 2).

Site visits

We made collecting trips on 31 June, 11 August 2014; 20 July, 17 August 2015; 19 July and 1 August 2016; and 28 June, 13 August 2017. Collecting trips were scheduled from 10:30 A.M. to approximately 5:00 P.M to span the blooming time of rockpinks. The weather for each collecting day was sunny and warm with scattered clouds and mild winds. Short droughts during July and August sometimes reduced the number of rockpink flowers.

Large-flowered rockpink

This rockpink population was discovered in 2001 when nearly 700 plants were counted on the sandstone exposure. This number compares to 1,800 in June of 2002, 2,430 in June of 2006, 2,743 individuals in July of 2009, and 1,500 in June of 2017. The increase in the number of individuals is likely due to management which made the site more suitable for rockpinks, and also more visible and easier to count.

Collecting

Two individuals participated in the collecting trips with one capturing insects with assistance from the other. We collected insects present on flowers opportunistically using a sweep net carefully placed over individual plants. No sweeping actions with the net were used to prevent damage to plants, including loss of flowers and seed. We selected a location within the outcrop, having a high density of rockpinks, as the primary collecting site during each trip (Droege 2016). This action was necessary because bee visits to flowers lasted not more than a few seconds. It was not practical to attempt to collect specimens from several meters away because of the short visiting time of bees, and the necessity of stepping slowly and carefully about the outcrop to avoid trampling of rockpinks.

Specimens

We had initial concern that some insect visitors could be rare, or even dependent upon large-flowered rockpink. These thoughts caused us to use caution and limit the number of specimens collected to reduce potential detrimental impacts on the rockpink/insect visitor community. The determination of the abundance of the various insect visitors was not an objective of the study. All insects collected were euthanized, transferred to a vial, and frozen upon returning to the laboratory. The specimens were sorted, and all insects, excluding Hymenoptera (bees), were pinned and identified. All bees were cleaned of pollen and debris so features critical to their identification could be easily examined. Cleaning was accomplished using warm, soapy water (dish detergent) with vigorous (shaking) agitation to remove all pollen and other debris (Droege 2016). The bees were rinsed, dried, fluffed using a hot air dryer, and pinned for identification (Droege 2016). Identifications were made using standard bee identification guides (Holm 2017). Nomenclature for plants follows Kiger (2003) and Mohlenbrock (2014), and the Integrated Taxonomic Information System (https://www.itis.gov/) for insects. All specimens were deposited in the entomology collection of Eastern Illinois University (EIU).

RESULTS

Large-flowered rockpinks initiated blooming in late May or early June at the Monroe County site, depending on local weather. Blooming continued into August with decreasing flower production. Blossoms opened between noon and 1:30 P.M., depending upon the amount of sunlight. Local weather was observed to influence the time of blooming in June of 2009 when flowers did not open until 3:30 P. M. due to cloud cover. Most flowers reached full anthesis within 30 minutes, and insects, mostly bees, were observed visiting blossoms before anthesis was complete. The rockpink population was estimated to have hundreds of highly visible pink to rose-colored flowers in bloom on the flat, open expanse of sandstone.

Flowers began to close between 4:00 to 5:00 PM as shading developed and direct sunlight decreased. Short droughts reduced flowering to a level estimated to be less than 50 blossoms per day throughout the entire site. Insect visits were much diminished during these times, and some collection trips failed to produce any specimens. Insect visitors were most abundant during June at the beginning of the rockpink blooming when large numbers of new flowers were available on a daily basis.

A total of 39 insects, representing the orders Hymenoptera (14 bee species), Diptera (two hoverfly species), and Lepidoptera (two butterfly species), were collected. The specimens included 13 native genera represented by 18 species common to the Midwest. All insect visitors were generalists, and no specimen was identified as a specific pollinator of *Phemeranthus* (Table 1). Bees (Hymenoptera) were the most represented taxa, including *Adrena* sp., *Augochlorella aurata* Smith, *Calliopsis adreniformis* Smith, *Ceratina calcarata* Robertson, *C. strenua* Smith, *Halictus ligatus* Say, *Lasioglossum hitchensi* Gibbs, *L. tegulare* Robertson, *L. trigeminum* Gibbs, *L. versatum* Robertson, *L. weemsi* Mitchell, M*egachile mendica* Cresson, *Melissodes bimaculatus* Lepeletier, and *Pseudopanurgus compositarum* Robertson (Table 1). All but two bee specimens were females that were collecting pollen as evidenced by the pollen attached to their abdomen or legs. Flower visits by bees were very brief, usually lasting just a few seconds before moving to another flower. Pollen was observed on all bees, and visits by large bees, such as *Melissodes bimaculatus* Lepeletier, caused the thin, wiry rockpink peduncles to collapse immediately to the sandstone only to quickly return to an upright position once the bee left.

Both hoverfly species were less active than bees, tending to remain on individual flowers for as much as several minutes. The sinuous hoverfly (*Hemipenthes sinuosa* Wiedemann) was a common flower visitor during June. Its numbers were observed to decrease as the blooming period progressed, and this insect was not seen during July and August, times when fewer flowers were present. The sweat bee (*Allograpta obliqua* Say) was present throughout the blooming period, and was sometimes difficult to distinguish from true bees due to its mimicry.

The two butterfly species, hackberry (*Asterocampa celtis* Boisduval and Leconte) and dainty sulfur (*Nathalis iole* Boisduval), were rare visitors to rockpink flowers. Their visits were very brief, and they usually did not move from flower to flower like bee visitors. They visited one flower, and left the outcrop after a visit of just a few seconds. The number of butterflies present at the same time within the entire study area never exceeded two individuals. Less than ten butterfly individuals were observed visiting flowers throughout the study.

Table 1: Insect visitors of large-flowered rockpink in Monroe County, Illinois. An "x" indicates the month of collection of specimens.

		Month of Collection		
Species	Sex	June	July	August
Adrena sp. (mining bee)	f	x		
Allograpta obliqua (oblique syrphid)	f	x		
Asterocampa celtis (hackberry)	-			x
Augochlorella aurata (sweat bee)	f	x	x	x
Calliopsis adreniformis (mining bee)	m	x		
Ceratina calcarata (carpenter bee)	f		x	
Ceratina strenua (nimble Ceratina)	f		x	
Halictus ligatus (ligated furrow bee)	f	x		
Hemipenthes sinuosa (sinuous hoverfly)	-	x		
Lasioglossum hitchensi (Hitchen's sweat bee)	f	x		x
Lasioglossum tegulare (Epaulate metallic sweat bee)	f	x		
Lasioglossum trigeminum (no common name)	f	x	x	x
Lasioglossum versatum (experienced sweat bee)	f	x		
Lasioglossum weemsi (Weem's sweat bee)	f	x		x
Megachile mendica (leafcutter bee)	f		x	
Melissodes bimaculatus (two-spotted longhorn bee)	f			x
Nathalis iole (dainty sulfur)	-			x
Pseudopanurgus compositarum (mining bee)	f	x		

Multiple capsules were observed following flowering on virtually every peduncle within the rockpink population. Capsules developed quickly following flowering and successful pollination, and begin releasing seeds once mature. The seeds were small (1 mm), black, reniform, and without ridges. Thousands of seeds were likely produced each year. Many likely fall onto bare sandstone, and may be washed away by rainfall. Others appear to fall into moss/lichen beds where they germinated and formed seedlings (Figure 2).

DISCUSSION

Bees of the genera *Adrena, Augochlorella, Calliopsis, Ceratina, Halictus, Lasioglossum*, *Megachile*, *Melissodes*, and *Pseudopanurgus* are native, solitary bees that actively gather pollen to feed to developing young (Dyer and Shinn 1978; Ginsberg 1984; Portman *et al*. 2019). All but two bee specimens were females with pollen on their abdomens or back legs, suggesting they were collecting it as food (Figure 1, Table 1). All bee species collected in this study are polylectic, meaning they collect pollen from flowers of many unrelated plant species (Gibbs *et al*. 2017; McCravy *et al*. 2019). Bees of the genera *Megachile* and *Ceratina* are above-ground nesters, but the remaining taxa are all below-ground nesting species that lay eggs on pollen balls placed within a system of underground tunnels (Danforth *et al*. 2019; McCravy *et al*. 2019).

Hoverflies were less common visitors of rockpink flowers at the Monroe County site. Adults feed on pollen, but do not collect it for use as food for young. They accomplish pollination inadvertently when they transfer pollen caught on their bodies from flower to flower (Klecka *et al*. 2018). Hoverflies (*Hemipenthes sinuosa* Wiedemann and *Allograpta obliqua* Say) were actively foraging during June, but *Hemipenthes* was absent in subsequent months when flower numbers were reduced by short droughts.

Butterflies feed on nectar or other sugar sources as adults. Dainty sulfur (*Nathalis iole* Boisduval) is a generalist species known to feed on nectar from several plant species. Hackberry (*Asterocampa celtis* Boisduval and Leconte) is known to feed on sap, rotting fruit, and nectar. Individuals of these butterflies made brief, very infrequent visits to rockpink flowers. Rockpink flowers contain nectaries, but little is known about their nectar producing capabilities. These short duration visits suggest nectar may be in amounts insufficient for these butterflies.

Rockpinks have a floral biology distinct from most plant species. New flowers are produced daily, but they remain open just a few hours before senescing. The production of new flowers each day greatly enhances the potential for successful pollination because insects do not waste time visiting old flowers that are no longer fertile. The potential for successful pollination is also increased by the early afternoon blooming of rockpinks, 12:30 to 4:00 P.M., which coincides with the time of day when sunlight is most direct and temperatures are highest, the hours of peak insect activity. The simultaneous timing of rockpink blooming and high insect activity is critical for the survival of rockpinks and their visitors at this site (Solga *et al*. 2020).

The process of pollination is mutually beneficial to plants and insects. It is also greatly influenced by a number of variables, including flower visibility and favorable weather (Buchman and Nabhan 1996; Geroff *et al*. 2014). Both factors could limit or cause pollination failure which could reduce or cause the loss of plant species from a community, resulting in the subsequent loss of insect taxa (Rathcke and Jules 1993; Biesmeijer *et al*. 2006; Geroff *et al*. 2014). Pollination is especially critical for plants restricted to small, unique, highly vulnerable habitats, such as rock outcrops (Hooper *et al*. 2012). Rock outcrop communities of the eastern United States are known for their rare, sometimes endemic, plant species (Baskin and Baskin 1988). The xeric nature of these communities limits competing plant growth, but rockpinks, with their succulent leaves and stems, thrive in these open, sparsely vegetated sites. The rockpink flowers are highly visible and accessible to foraging insects due to the absence of competing vegetation (Heinrich 1975; Newman *et al*. 2019). The current vegetative composition of the rock outcrop appears to be very favorable for rockpinks based on the observations of high numbers of developing capsules and subsequent seed production.

Increased growth of woody and herbaceous plants could disrupt rockpink flower visitor interactions by reducing flower visibility and accessibility to foraging insects. The large-flowered rockpink population at Castle Rock in Randolph County decreased from hundreds of plants in 1954 to none in 2019, a period when woody and herbaceous plants were observed to increase substantially in density and size, eventually creating continuous shade and increased competition for the rockpinks (Newman *et al*. 2019). Maintaining a sparse vegetative cover that allows for high visibility of and accessibility to rockpink flowers to visiting insects is essential for the long-term survival of this species at this site.

Changing weather patterns may affect rock outcrop communities in Illinois and other states in the future. The Monroe County rock outcrop was significantly affected by several high rainfall events during the study. These episodes of high precipitation washed soil onto the outcrop, promoting the rampant growth of lesser ragweed (*Ambrosia artemisifolia* L.), and providing soil for the expanded growth of Japanese honeysuckle (*Lonicera japonica* L.), necessitating their removal to prevent permanent damage to the rockpink outcrop vegetation. Vegetation control is thought to be a management problem of many rock outcrop communities. Documentation of insect visitor/rare plant interactions at these sites is needed to develop strategies for their long-term preservation.

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A Rare Mixed-Oak Sand Flatwoods Community, Iroquois County Conservation Area, Illinois

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Abstract: Sand flatwoods communities dominated by *Quercus palustris* (pin oak) are occasionally encountered in the Kankakee Sands Region of the Grand Prairie Natural Division in northeastern Illinois. These communities are typically found in depressions subject to ponding from a seasonally high water table. Recently, a rare mixed-oak sand flatwoods community was encountered. This previously undescribed community type is slightly elevated above the typical sand flatwoods and therefore elevated above and influenced less by groundwater. The area is still largely flat but with slight depressions that collect rainwater. Here, *Q. ellipsoidalis* (Hill's oak) dominates with an Importance Value (IV200) of 116.1, (200 possible), *Q. palustris* is also common (IV200 of 72.0), while *Q. alba* (white oak) is occasional (IV200 of 10.6). This community has a well-developed woody understory; seedlings and saplings of *Q. ellipsoidalis* and *Q. palustris* are very common along with the shrubs *Vaccinium angustifolium* (low-bush blueberry) and *Aronia melanocarpa* (black chokeberry). Mean cover of ground layer vegetation averages 80%. The dominant herbaceous species is *Carex pensylvanica* (Pennsylvania sedge). Overall, this unique community type had low species diversity, especially in the canopy and ground layer.

Introduction

Sand deposits account for nearly 5% of the land surface of Illinois, one of the largest being the Kankakee Sand Area Section of the Grand Prairie Natural Division located in parts of Grundy, Iroquois, Kankakee, and Will counties, Illinois, and adjacent Newton County, Indiana (Schwegman *et al.* 1973). Occurring on glacial outwash plains associated with erosion events of Wisconsin glaciation, this sand deposit remained after glacial lakes were drained about 14,500 years ago during the Kankakee Torrent (King 1981; Willman and Frye 1970).

Sand flatwoods are relatively rare communities, only a few being found in the Kankakee sand deposits, and are very rare or non-existent from the other sand areas of Illinois. This community type, where dominated by *Quercus palustris* (pin oak), has been studied (McDowell *et al.*1983; Phillippe et al 2009, 2010), but a sand flatwoods community dominated by *Q. ellipsoidalis* (Hill's oak), *Q. palustris*, and *Q. alba* (white oak) has not previously been described in Illinois. The present study was undertaken to determine woody species composition and structure, and the floristic composition of the ground layer vegetation in a mixed-oak sand flatwoods community at the Iroquois County Conservation Area (ICCA).

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Description of the Study Area

The ICCA is situated at the edge of former glacial Lake Watseka, drained during the Kankakee Torrent, leaving sandy beaches and near-shore sand deposits (Willman and Frye 1970; Willman 1973; Curry *et al.* 2014). These sands were reworked by wind creating the present-day dune and swale topography of the region. The characteristic sand savanna, sand prairie, and sedge meadow vegetation became established during the Hypsithermal period about 8,000 years ago (King 1981).

The ICCA, which encompasses 7.8 km^2, is located in extreme northeastern Iroquois County about 6 km northeast of the town of Beaverville. The flatwoods studied is located in the southeast part of the ICCA (SE1/4 SE1/4 Sec 24 T29N R11W; 40.98262°N/87.54307°W). Purchased by the Illinois Department of Conservation in 1944 as a prairie chicken sanctuary, the ICCA is now used principally as a hunting area. Based on historical aerial photography interpretation, when purchased most of the area had been heavily grazed and attempts had been made to drain the extensive sedge meadow and marsh communities in the southwest part of the preserve (Illinois State Geological Survey 2008). Hedborn (1984) studied the vascular flora of Iroquois County through thorough literature search and field studies and includes information on presettlement vegetation, soils, settlement history, and vegetation types. McDowell *et al.* (1983) described the composition and structure of the savanna communities of the ICCA, and more recently, Phillippe *et al.* (2002) and Phillippe *et al.* (2009) reported on the vascular flora of ICCA. Management of the site has included prescribed burns, efforts to remove invasive species (e.g., *Phalaris arundinacea* [reed canary grass]) and aggressive species (e.g., *Populus tremuloides* [quaking aspen], and *Salix* spp. [willow]), and levee repair (Eric Smith, IDNR Natural Heritage, personal communication).

The sand flatwoods, found in depressions between the dunes, are on Watseka loamy sands and Morocco fine sands (Wascher *et al.* 1951; Keifer 1982). These soils, derived from sandy outwash sediments, consist of 1-meter or more of acid, peaty sand over clay with a black surface horizon, and are poorly drained. Furthermore, Morocco fine sands are said to have a minor component (3%) of Maumee soils, for which the USDA Web Soil Survey gives an ecological site description of wet sandy flatwoods (F097XA008MI) (Soil Survey Staff, NRCS, USDA 2020). Climate at the ICCA is continental with warm summers and cold winters. Mean annual precipitation is 98.0 cm, with May having the highest rainfall (11.5 cm). Mean annual temperature is 9.9°C with the hottest month being July (average of 23.6°C), the coldest January (average of −5.7°C). Frost free days range from 141 to 206, with an average of 174 days per year (Midwestern Regional Climate Center 2009, Kankakee, Illinois).

METHODS

On October 9-10 and 19, 2007, the vegetation of the mixed-oak sand flatwoods was studied using a 100 m × 100 m (1-ha) area divided into contiguous quadrats 25 m on a side (16 quadrats). This 1-ha plot was placed near the center of the flatwoods, all sides at least 10 m from the community boundary. In each quadrat all living woody stems ≥10.0 cm dbh were identified and their diameters recorded. From these data, density (stems/ha), basal area (m^2/ha), relative density, relative dominance, importance value (IV), and average diameter (cm) were calculated for each species. Determination of the IV follows the procedure used by McIntosh (1957) and is the sum of the relative density and relative dominance (basal area) or IV200. Botanical nomenclature for most species follows Mohlenbrock (2002); nomenclature for endangered and threatened species follows the Illinois Endangered Species Protection Board (2020).

During the field work, some oak individuals not typical of *Quercus ellipsoidalis* were encountered. Representative specimens were sent to Dr. Andrew Hipp, an oak specialist at The Morton Arboretum, who verified that some of the specimens represented introgression with *Q. velutina* (black oak) (e-mail, 16 October 2014), a conclusion verified by Dr. Gerould Wilhelm (e-mail, 16 October 2014). These specimens are included under *Q. ellipsoidalis* in this study.

Woody understory composition and density (stems/ha) were determined using nested circular plots 0.0001, 0.001, and 0.01 ha in size. The nested plots were located at about 25 m intervals along four transects through the study area (20 sets of circular plots). Four additional 0.0001 ha circular plots were located 6 m from the center points along cardinal compass directions. Woody seedlings (≤50 cm tall) were recorded in the 0.0001 ha plots; small saplings (>50 cm tall and <2.5 cm dbh) in the 0.001 ha circular plots; and large saplings (2.5-9.9 cm dbh) in the 0.01 ha circular plots.

The ground layer vegetation was sampled along two 25-m long transects. Along each transect, 1.0 m^2 plots were located at 1-m intervals (n = 25/transect) and offset a random distance (0-9 m) from the transect, with odd-numbered quadrats positioned to the right, even-numbered to the left. A random numbers table was used to determine the offset distance each quadrat was placed from the transect line. Cover of each species was determined using the Daubenmire cover class system (Daubenmire 1959) as modified by Bailey and Poulton (1968). Importance value (IV200) was determined by summing relative cover and relative frequency.

RESULTS

The mixed-oak sand flatwoods at the ICCA, like most other Illinois examples of sand flatwoods communities, is small, being less than 3 ha in size. The flatwoods had few species, as only 22 species were recorded in all sampling plots (Tables 1, 2, and 3). All species observed in the sampling plots were native. Four species were recorded in the tree plots, seven in the large sapling plots, sixteen in small sapling plots, thirteen in seedling plots, and fourteen in the ground layer plots. Despite having low species diversity, this portion of ICCA is home to seven Illinois endangered plant species (*Carex cumulata* [clustered oval sedge], *Carex straminea* [eastern straw sedge], *Hypericum adpressum* [shore St. John's wort], *Persicaria careyi* [Carey's smartweed], *Scleria pauciflora* [few-flowered nut rush], *Sisyrinchium atlanticum* [eastern blue-eyed grass], and *Vaccinium corymbosum* [high-bush blueberry]) and one Illinois threatened plant species *Drosera intermedia* (narrow-leaved sundew) (Illinois Natural Heritage Database, Jeannie Barnes personal communication; Illinois

Table 1: Density by diameter class (stems/ha), basal area (m^2/ha), relative density, relative dominance, importance value (IV200), and average diameter for the woody species recorded for a mixed-oak sand flatwoods community, Iroquois County Conservation Area, Iroquois County, Illinois.

	Diameter Classes (cm)										
Species	10-19	20-29	30-39	40-49	50+	Total#/ ha	Basal Aream^2/ha	Rel. Den.	Rel. Dom.	IV200	Avg. Diam.(cm)
Quercus ellipsoidalis	12.0	59.0	40.0	11.0	1.0	123.0	8.665	53.0	63.1	116.1	28.9
Quercus palustris	32.0	40.0	19.0	1.0	–	92.0	4.441	39.7	32.3	72.0	23.6
Quercus alba	10.0	4.0	–	–	1.0	15.0	0.568	6.5	4.1	10.6	19.9
Nyssa sylvatica	1.0	1.0	–	–	–	2.0	0.058	0.8	0.5	1.3	18.9
Totals	55.0	104.0	59.0	12.0	2.0	232.0	13.732	100.0	100.0	200.0	

Endangered Species Protection Board 2020). Only *Vaccinium corymbosum* was observed in our sampling plots for the current study.

The woody overstory of the flatwoods averaged 232 stems/ha with a basal area of 13.7 m^2/ha (Table 1). Only four tree species were recorded in the tree plots and only two (*Quercus ellipsoidalis* and *Q. palustris*) were common and represented in the larger tree size classes. *Q. ellipsoidalis* dominated and accounted for nearly 58% of the canopy (IV200 of 116.1), *Q. palustris* ranked second in importance (IV200 of 72.0) followed by *Q. alba* (IV200 of 10.6); there also were a few individuals of *Nyssa sylvatica* (black gum) (Table 1). Both *Q. ellipsoidalis* and *Q. palustris* were common and evenly distributed throughout the mixed-oak sand flatwoods. *Q. ellipsoidalis* was most abundant in the larger size classes (20-29, 30-39, and 40-49 cm) while *Q. palustris* was abundant in the smaller size classes (10-19 and 20-29 cm).

Sassafras albidum (sassafras) and *Populus grandidentata* (big-tooth aspen) were the most abundant large saplings with 215 and 140 stems/ha respectively.

Table 2: Density (stems/ha) of seedlings, small saplings and large saplings encountered in a mixed-oak sand flatwoods community, Iroquois County Conservation Area, Iroquois County, Illinois. Seedlings = woody stems < 0.5 m; small saplings = stems > 50-cm tall and < 2.5 cm dbh (diameter at breast height); large saplings = stems > 2.5 cm dbh and < 10 cm dbh.

Species	Seedlings	Small Saplings	Large Saplings
Vaccinium angustifolium	121,500	9,150	–
Quercus ellipsoidalis	4,900	5,950	20
Quercus palustris	4,400	950	–
Aronia melanocarpa	3,500	21,150	–
Spiraea tomentosa	2,200	2,700	–
Gaylussacia baccata	1,300	2,500	–
Quercus alba	900	550	20
Rubus flagellaris	600	–	–
Sassafras albidum	500	4,000	215
Salix humilis	300	–	–
Prunus serotina	200	600	40
Rhus copallina	200	1,500	5
Nyssa sylvatica	100	50	5
Populus grandidentata	–	1,100	140
Rubus allegheniensis	–	300	–
Populus tremuloides	–	300	–
Vaccinium corymbosum	–	200	–
Spiraea alba	–	150	–
Totals	140,600	51,150	445

Table 3: Frequency (%), mean cover (% of total cover), and importance value (IV) of the species encountered in the ground layer of a mixed-oak sand flatwoods community, Iroquois County Conservation Area, Iroquois County, Illinois. IV = relative frequency (frequency/sum frequency) + relative cover (mean cover/sum cover).

Species	% Freq.	Mean Cover	IV200
Vaccinium angustifolium	70	39.27	69.5
Rubus hispidus	98	21.67	56.1
Carex pensylvanica	76	5.54	29.5
Quercus ellipsoidalis	26	5.24	14.2
Gaylussacia baccata	12	5.10	9.9
Quercus palustris	18	1.97	7.7
Spiraea tomentosa	12	0.21	3.9
Sassafras albidum	6	0.18	2.0
Aronia melanocarpa	4	0.60	1.9
Rubus flagellaris	4	0.12	1.3
Prunus serotina	4	0.02	1.3
Dichanthelium acuminatum	2	0.30	1.0
Rhus copallina	2	0.30	1.0
Solidago canadensis	2	0.06	0.7
Totals		80.58	200.0
Bare Ground/Litter		22.92	

Relatively few oaks were recorded in the stratum with 20 stems/ha of *Quercus ellipsoidalis* and *Q. alba* (Table 2). Small saplings (51,500/ha) and seedlings (140,600/ha) were abundant. Woody shrub species *Aronia melanocarpa* (black chokeberry) (21,150 small saplings/ha and 3,500 seedlings/ha) and *Vaccinium angustifolium* (low-bush blueberry) (9,150 small saplings/ha and 121,500 seedlings/ha), both colonial spreading shrubs, were the most important. Oaks were also well represented with 5,950 small saplings and 4,900 seedlings of *Q. ellipsoidalis* and 950 small saplings/ha and 4,400 seedlings/ha of *Q. palustris*.

The ground layer vegetation (herbaceous species and woody plants ≤50 cm tall) was patchy but mostly dense with bare ground and litter averaging only 22.9% (Table 3). Fourteen species were recorded in the ground layer sampling plots. *Carex pensylvanica* (Pennsylvania sedge) with an IV200 of 29.5) was the only non-woody species important in this stratum (Table 3). The most important species in this stratum were shrub species. *Vaccinium angustifolium* had an IV200 of 69.5 and *Rubus hispidus* (bristly dewberry) had an IV200 of 56.1. Oak species were also present in the ground layer.

Discussion

Sand flatwoods dominated by pin oak are rare in Illinois (White 1978), primarily restricted to a few small sites in Iroquois, Kankakee, and Cook counties. Most notably, sand flatwoods are known from ICCA (McDowell *et al.* 1983) and adjacent Hooper Branch Nature Preserve, both in Iroquois County (Phillippe *et al.* 2009, 2010), as well as Zander Woods (Thornton-Lansing Road Nature Preserve) and Jurgensen Woods (Jurgensen Woods North Nature Preserve) in Cook County. Only 21 acres of high-quality (Grade B) sand flatwoods occur in Illinois, all at Zander Woods (White 1978). Taft *et al.* (1995) documented additional flatwoods in Washington County (Chip-O-Will and Recker Woods), Illinois that have >50% sand in the A horizon and could also be classified as sand flatwoods. Faber-Langendoen (2001) states there are probably fewer than 100 occurrences throughout the range and only 18 occurrences documented in Illinois, Indiana, and Michigan. Most are small, a few hectares in size; pin oak dominates most sites with occasional white oak. *Quercus stellata* (post oak) is the dominant species at Washington County sites.

Mixed-oak sand flatwoods dominated by *Quercus ellipsoidalis*, *Q. palustris*, and *Q. alba* are very rare. We only know of the example described in this article. Throughout the ICCA the water table is near the ground surface, causing ponding of lowland areas during the spring and sometimes early summer. Since the mixed-oak sand flatwoods community is at a slightly higher elevation, ponding is for a shorter duration than in the pin oak sand flatwoods. The ground layer of sand flatwoods communities rarely exceeds 25% cover, while bare sand and litter account for over 75% (Phillippe *et al.* 2009, 2010). The mixed-oak sand flatwoods studied in this article had over 80% cover and bare ground and litter was 23%. The shorter duration of ponding in this mixed- oak sand flatwoods is likely a reason for the more extensive ground layer, particularly the shrubby species. This increased shrub cover is likely a primary reason for low species diversity in the herbaceous layer.

Long-term fire suppression followed by infrequent prescribed burns is also a likely reason for high cover of colonial shrub species. As with other natural communities in the Kankakee Sands, the natural communities at ICCA are part of a fire-adapted system (Nuzzo 1986; Consadine 2009; Consadine *et al.* 2013). The sand savannas and flatwoods of this area; however, are different today compared to pre-settlement time in the early 1800's (Phillippe *et al.* 2011). Originally, natural fires and those set by early aborigines decreased woody invasion. Likewise, early settlers used fire to maintain open pasture (McClain and Elzinga 1994). Until management resumed in the Midwest in recent decades there was a long period of reduced fire frequency followed by a total absence of fire. This absence of fire, even for just a few decades, has resulted in dramatic loss of oak savanna habitat in the Midwest (Taft 1997).

Historical aerial photography from 1940 shows this area to be very open (Illinois State Geological Survey 2008). Only scattered trees were present, likely a result of past grazing and fire. This area is thought to have been a wet sand flatwoods community based on the current composition and its landscape setting, as similar sites exist elsewhere at ICCA (Phillippe *et al.* 2002) and adjacent Hooper Branch (Phillippe *et al.* 2010). Historically this area might also have been wet shrub prairie or wet to wet-mesic sand prairie. White (1978) points out that without fire these communities can succeed to sand flatwoods. In recent decades this part of ICCA has been burned in 1999, 2003, and 2012 (Eric Smith, IDNR, personal communication). Increased fire management should promote the more fire-tolerant *Quercus ellipsoidalis* while an intermediate or infrequent fire management regime could favor pin oak. Currently, this site appears to have sufficient recruitment of both *Q. ellipsoidalis* and *Q. palustris* to have sustainable canopy composition.

A major problem facing the ICCA is the loss of ground water due to ditching efforts on the surrounding farmland and the increased use of centra-pivot irrigation systems in the area. This de-watering has resulted in the loss of the marsh communities along the east edge of the ICCA, while the extensive sedge meadow in the southwestern part of the preserve has become drier. The sand flatwoods are also dependent on this high water table. The lowering of the water table will undoubtedly result in successional changes and may have contributed to the mixing and apparent hybridization of multiple species in the red oak group, including *Quercus ellipsoidalis*, *Q. velutina*, and *Q. palustris*.

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Vegetation of Wind-blown Glacial Sand Deposits along the Illinois River - A Review

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Abstract: This study is a review of the vegetation of the major plant communities in the wind-blown glacial sand deposits of the lower Illinois River Valley (inland sand deposits of H. A. Gleason). Most of these studies were conducted between 1999 through 2007, with a few into the present. Approximately 1086 km^2 of sand deposits occur on the terraces and uplands surrounding the Illinois River from the "Big Bend" region near Hennepin, Putnam County, south into Greene County, Illinois. These deposits vary in size from a few hectares to the deposit centered in Mason County which covers approximately 570 km^2. Most sand deposits are now cultivated, with small remnants of protected natural vegetation in nature preserves and a state forest. These natural areas contain many high-quality sand communities, including sand ponds, sand seeps, a tall shrub fen, a sedge meadow, sand prairies, a dry gravel prairie, sand savannas, and sand forests.

Introduction

Wind-blown glacial sand deposits are common in the northern half of Illinois, the result of erosional events associated with Wisconsinan glaciation (Willman and Frye 1970; Schwegman 1973; King 1981). Sand deposits account for nearly 5% of the land surface of Illinois, the most extensive being the Kankakee River sand deposits of northeastern Illinois, and the Illinois River sand deposits in the central part of the state (Gleason 1910; Schwegman 1973). The Kankakee River sand deposits were formed when glacial lakes drained about 14,500 BP (before present) after glacial moraines were breached, resulting in the Kankakee Torrent (Willman 1973). The Illinois River sand deposits, referred to as "the inland sand deposits" by Gleason (1910), were formed when the waters of the Kankakee Torrent slowed upon entering the broad lowlands of the Illinois River below the "Big Bend" near Hennepin, Illinois (Figure 1).

These sand deposits, known as the Parkland Formation, consist of windblown sand in dunes and sheet-like deposits between and bordering dunes (Willman and Frye 1970). The Parkland Formation is usually found on terraces along major river valleys in the northern half of Illinois. These sands were reworked by wind, creating a characteristic dune and swale topography. Dunes, 1- to 12-m high, are common and occasional dunes exceed 30 m. To some extent, these dunes have migrated onto the bluffs and uplands lying east of the Illinois River terraces due to prevailing westerly winds (Gotsch 1989).

Hart and Gleason (1907), Gleason (1910), Vestal (1913), and Sampson (1921) were the first to describe the major plant communities and associated animals of these deposits. Since these early studies, only occasional articles, mostly concerned with a particular nature preserve or community type, have been published. Though most of the land is now under cultivation, a fairly extensive preserve system has maintained some of this diversity (McFall and Karnes 1995).

The plant communities of these sand deposits are highly varied and include sand ponds, sand seeps, tall shrub fen, sedge meadow, wet-mesic sand prairie, dry sand prairie, dry gravel prairie, sand savanna, and sand forest (McFall and Karnes 1995). The present review was undertaken to characterize the vegetation structure and dominant and representative species of these major plant communities in the glacial sand deposits of the

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Figure 1. Map of the Illinois River valley sand deposits from the "Big Bend" in Putnam County south to the confluence with the Mississippi River in Jersey County. The numbers in the counties refer to separate sand deposits listed by county and defined in Table 1 (see left column).

Illinois River Section of the Illinois River of the Mississippi River Sand Areas Natural Division (Schwegman 1973). These studies mostly were conducted by the authors from 1999 to 2007 with a few additional observations and studies recently completed.

MATERIALS AND METHODS

Vegetation Sampling

Woody Overstory Survey

Typically, a 100 m by 200 m section of study sites with a tree canopy was surveyed, mostly during midsummer, by dividing the area into contiguous quadrats 25 m on a side for a total of 2.0 ha (32 plots). Sometimes a smaller or larger area was surveyed depending on the size of the study site and the reason(s) for the study. All living and dead-standing woody individuals ≥10.0 cm dbh (diameter at breast height, considered 1.4 m above the ground) were identified and their diameters recorded. From these data, living-stem density (stems/ha), basal area (m^2/ha), relative density, relative dominance, importance value (IV of 200 possible), and average diameter (cm) were calculated for each species. Determination of the IV follows the procedure used by McIntosh (1957) and is the sum of the relative density and relative dominance (basal area). Multiple-stemmed trees (coppices) were recorded as separate individuals.

Change in overstory cover within the Sand Ridge State Forest (Mason County, Illinois) was measured using aerial photographs from 1939, 1957, 1969, 1988, and 1998 that were digitized to determine the extent of woody encroachment (trees and large shrubs). These photographs were borrowed from the University of Illinois Map Library and scanned with a Microtek ScanMaker. A total of 20 stratified randomly located 5 ha circular plots (100 ha total area), representing approximately 20% of the study site, were interpreted and then digitized using ARC/INFO.

Woody Understory Survey

Woody understory composition and density (stems/ha) were determined using nested circular plots 0.0001, 0.001, and 0.01 ha in size located at 15 m intervals along randomly located transects within the study area. Four additional 0.0001 ha circular plots were located 7 m from the center points of each original plot along cardinal compass directions. In the 0.0001 ha plots, woody seedlings (≤50 cm tall) were counted, in the 0.001 ha circular plots, small saplings (>50 cm tall and <2.5 cm dbh) were recorded, and in the 0.01 ha circular plots, large saplings (2.5-9.9 cm dbh) were tallied. The number of center points used was determined by the number of overstory plots.

Ground-Layer Vegetation

Quantitative sampling was conducted in mid- to late-summer using 1-m^2 quadrats located at 1 m intervals along one to six (depending on size and species diversity of the study site) randomly placed 25 m long transects (sometimes longer). Even-numbered quadrats were placed to the right, odd-numbered quadrats to the left of each transect. A random numbers table was used to determine the number of meters a quadrat was placed from a transect line (0 up to 9). Percent cover of each species encountered was determined using the Daubenmire (1959) cover class system as modified by Bailey and Poulton (1968): class 1 = 0-1%; class 2 = >1-5%; class 3 = >5-25%; class 4 = >25-50%; class 5 = >50-75%; class 6 = >75-95%; class 7 = >95-100%. From these data, frequency (%), mean cover (%), relative frequency, relative cover, and importance value (IV of 200 possible) were determined.

Voucher specimens

For most plant communities voucher specimens of most plant species found were collected, identified, and deposited in the herbaria of the Illinois Natural History Survey, Champaign, Illinois (ILLS), and the Stover-Ebinger Herbarium of Eastern Illinois University, Charleston, Illinois (EIU). The study sites were visited 9 to 12 times during the growing season for two consecutive years, and habitat, along with other pertinent data, recorded. Criteria for designating non-native species followed Mohlenbrock (2002) and Gleason and Cronquist (1991), while nomenclature followed Mohlenbrock (2002). Also, we recorded the location of all threatened and endangered plant species found, but unless very common on the site, were not collected (Herkert and Ebinger 2002; IESPB 2020). For many of the studies, a species list has been published separately.

Field Evaluation

To find possible new high natural quality sites for the plant communities, we conducted a drive-through survey of all sand deposits of the Illinois River Valley from near Hennepin, Putnam County, south into Greene County (Willman and Frye 1970; Figure 1). This survey was conducted during the winter and spring of 2006 and did not include dedicated nature preserves because they had been previously examined and mostly surveyed on previous trips. To complete this survey, soil maps of the entire study area were examined and the sand deposits marked on county road maps. These areas were then examined for high-quality sand communities by traveling all roads (and many farm lanes) in these sand areas and included a great deal of hiking. The classification and community descriptions of White and Madany (1978) were used to determine the quality of prospective sites. The very few potential new sites found were visited during the summer and fall of 2006. The observations and results found during this extensive examination of the Illinois River sand areas are discussed in the Description of the Study Area in this review. Also, included are observations made while driving to and from study sites, along with other trips looking for potential study sites. Also included is the general location and habitat of endangered and threatened plant species found during the study.

RESULTS AND DISCUSSION

Description of the study area

Wind-blown glacial sand deposits along the lower Illinois River extend as a series of small to relatively large areas of exposed sandy soil from the "Big Bend" region of the Illinois River near Hennepin, Putnam County, south into Greene County (Figure 1). These isolated deposits, mostly located on the east side of the Illinois River, are listed along with their geographic and topographic positions, size (km^2), and the county soil surveys used to determine the area of each deposit (Table 1).

In the northern counties (Putnam, Marshall, and Woodford), the sand deposits are mostly situated on gently rolling uplands (Zwicker 1992; Teater 1999; Teater and Walker 2002). These sands were deposited during the highest floods of the Kankakee Torrent when floodwaters overtopped uplands to the east of the Illinois River Valley. In Peoria, Tazewell, and Mason counties, and south, the sand deposits are common on terraces but also extend into the uplands, the result of strong westerly winds. The sand area in Peoria County is unique (Figure 1), being the only large deposit on the west side of the river (Walker 1992). In addition to the two small sand deposits in northern Tazewell County, there are two relatively large deposits in the southern part of the county that extend south in Mason County (Tazewell 3 and 4, in Figure 1; Willman and Frye 1970; Teater 1996). This large sand deposit extends across most of the western part of Mason County (Calsyn 1995) and covers an area of approximately 569.8 km^2 of Mason County, with the two extensions into Tazewell County adding another 124.3 km^2 (Table 1).

The sand deposit in Mason County, the largest in the Illinois River Valley, extends as a broad northeast-southwest band of sand 8 to 15 kms wide and about 50 kms long (Mason 1, in Figure 1). The western boundary includes the floodplain and terrace of the Illinois River, while the southern and southeastern boundaries comprise the uplands adjacent to the Sangamon River. The topography within this deposit consists of flat to gently rolling terrace and upland. Dune fields are common, including some large, steep-sided dunes that exceed 30 m in height (Willman and Frye 1970; Calsyn 1995). The Illinois endangered *Stylisma pickeringii* (Torr.) Gray var. *pattersonii* (Fern. & Schub.) Myint. (Patterson's bindweed) is located on private land at the southern tip of this extensive sand deposit about 1 km southwest of Snicarte, Illinois (SW1/4 S4 T19N R10W) (Claerbout *et al.* 2010; Phillippe *et al.* 2011).

High quality sand communities are encountered in the Mason County sand deposit in a series of nature preserves mostly purchased between 50 and 80 years ago by the State of Illinois (McFall and Karnes 1995). Also, sand communities occur in Sand Ridge State Forest located just west of Forest City, Illinois. Initial land purchases for this site began in 1939, and from the 1940's into the 1950's pine plantations were established on old pastureland, abandoned cultivated fields, and dry sand prairies that were scattered throughout this state forest. Presently, 1,012 ha of marketable pine plantations

Table 1: Illinois county and sand deposit number, geographic area, topographic position (terrace or upland), extent of the sand deposit (km^2), and the county soil surveys used to determine the extent of the sand deposits along the Illinois River valley from the "Big Bend" in Putnam County, south to the Mississippi River in Jersey County. *see Figure 1.

County and Number*	Geographic Area	Topographic Position	Area (km^2)	County Soil Survey
Putnam #1	Hennepin	upland	25.9	Zwicker (1992)
Putnam #2	Senachwine	upland	10.4	Zwicker (1992)
Marshall #1	Lacon	upland	18.1	Teater and Walker (2002)
Woodford #1	Spring Bay	upland	28.5	Teater (1999)
Peoria # 1	Chillicothe	terrace	46.6	Walker (1992)
Tazewell # 1	Pekin	terrace	10.4	Teater (1996)
Tazewell # 2	Powerton	terrace	7.8	Teater (1996)
Tazewell # 3[a]	SW extension	upland	82.9	Teater (1996)
Tazewell # 4[a]	SE Extension	upland	41.4	Teater (1996)
Mason # 1	W ½ of co.	terrace/upland	569.8	Calsyn (1995)
Menard # 1[b]	Oakford	upland	25.9	Fehrenbacher and Odell (1953)
Cass # 1	Beadstown	terrace	20.7	Calsyn (1989)
Cass # 2	Airport	terrace	59.6	Calsyn (1989)
Cass # 3	Arenzville	terrace/upland	51.8	Calsyn (1989)
Cass # 4[c]	S extension	terrace	13.0	Calsyn (1989)
Morgan # 1	Meredosia	terrace	20.7	Gotsch (1989)
Scott # 1	Naples	terrace	15.5	Gotsch (1989)
Scott # 2	dune fields	terrace/upland	33.7	Gotsch (1989)
Greene # 1	Apple River	upland	2.6	Downey *et al.* (1974)
Greene # 2	Macoupin Cr.	upland	1.0	Downey *et al.* (1974)

[a]These sand deposits are extensions of the major sand deposit of Mason County.
[b]About half of this sand deposit is in Cass County, and includes three deposits of 20.7 km^2, 3.9 km^2, and 1.3 km^2, respectively, the two smaller being completely in Menard County.
[c]This sand deposit has a north/south extent of about 14 miles and extends through Morgan and the northern part of Scott counties and totals about 49.2 km^2, 13.0 km^2 in Cass County, 20.7 km^2 in Morgan County, and 15.5 km^2 in Scott County.

occur in the state forest while most of the remainder is degraded oak and oak-hickory sand savannas and sand forest along with some dry sand prairie inclusions (McFall and Karnes 1995; Andrews 2004).

Sand deposits are also found along the lower part of the Sangamon River, a major tributary of the Illinois River, that forms the boundary between Mason, Cass, and Menard counties (Figure 1). These sand deposits, which occur in northeastern Cass and northwestern Menard counties (Menard 1, in Figure 1), were formed in post-glacial times by prevailing westerly winds that blew sand through the Sangamon River Valley (Fehrenbacher and Odell 1953; Willman and Frye 1970; Calsyn 1989). Found on the upper terrace and associated hills to the south of the Sangamon River, these deposits consist of small lenses of sand on the flanks and in the valleys of hills adjacent to the river, and most are less than a few hundred ha in size (Table 1).

To the south of the Sangamon River most of the sand deposits are on the Illinois River terrace in Cass, Morgan, Scott, and Greene counties (Figure 1, Table 1). The majority of these consist of long, narrow, relatively shallow ridges of sand having a north/south orientation (Calsyn 1989; Gotsch 1989; Downey *et al.* 1974). These low sand ridges, some with an elevation of less than a meter above the surrounding Illinois River terrace, have migrated to the east along the Illinois River terrace due to the prevailing westerly winds. Though most are on the Illinois River terrace, some sand dunes were blown onto the flanks of the hills east of the terraces, the sand sometimes extending to the ridge tops (Table 1). The largest of these ridges extends from southern Cass County through Morgan into Scott County. Around and to the north of Arenzville in Cass County (Cass 3, in Figure 1), sand deposits are in the uplands bordering the Illinois River terrace. Degraded sand savanna and sand forests are common throughout these uplands. During our travels we found all were of poor quality due to past logging, grazing, and fire suppression. The Illinois threatened species *Astragalus distortus* Torr. & A. Gray (bent milk vetch) is known from the Sand Creek Cemetery northwest of Glasgow, Illinois. This cemetery is at the extreme southern edge of the most southern sand deposit in Scott County (McClain and Ebinger 2003; Phillippe *et al.* 2011).

Many rare taxa of the vascular flora in the Illinois River Sand Area are well documented due to the efforts of the amateur botanist, Rollo T. Rexroat (1893-1979) of Virginia, Cass County, Illinois. Mr. Rexroat operated a general store with his brother in the city of Virginia during the early part of the last century. His working hours were at the store, but evenings and weekends were spent searching the sand areas for vascular plants. He once said "I have driven 40,000 miles and walked about 50,000 more" during his survey for plants. These efforts resulted in the collection of nearly 11,000 specimens, including 14 not previously known from the state, 20 that had not been located for nearly a century, and 40 others that are infrequently observed (Dolbeare 1973). Among these is a member of the Cyperaceae, *Lipocarpha maculata* (Michx.) Torr., collected at the edge of a temporary sand pond in Cass County in the 1960s, but not seen since. Mr. Rexroat was meticulous with his collecting and specimen preparation and donated his collection to the Illinois State Museum where they continue to be a valuable data source for field research on plant diversity within the Illinois Sand Areas.

Sand Communities

The sand and some associated natural communities studied in the Illinois River Section of the Illinois River of the Mississippi River Sand Areas Natural Division (Schwegman 1973) are discussed below. The natural community names used are mostly those of White and Madany (1978) and the Illinois Natural Area Inventory directed by White (1978). Similar reports are available for two smaller sand areas in northwestern Illinois: the Mississippi River Section of the Illinois River and Mississippi River Sand Areas Natural Division (Ebinger *et al.* 2006), and the Green River Lowland Section of the Grand Prairie Natural Division (Ebinger *et al.* 2009).

Sand Pond

According to Government Land Office survey records wetlands were a common landscape feature of the sand deposits of the Illinois River Valley prior to European settlement (Rodgers and Anderson 1979). At that time the water table was close to the surface, many sand ponds were permanent or only rarely became dry in late summer or during drought years. Presently, most sand ponds of the Illinois River sand deposits are ephemeral and farmed in most years. The time between extensive flooding of these sand ponds may be 20 years or more.

Schwegman (1984) described wetlands on agricultural lands near Snicarte in Mason County during the wet year of 1974 when many emergent wetland plant species dominated flooded agricultural fields throughout the growing season. These fields were flooded from the fall of 1993 to late summer of 1995 (McClain *et al.* 1997). At that time, the authors collected 72 vascular plant species from five temporary ponds that inundated farm fields in Cass and Mason counties, Illinois. Illinois endangered and threatened plant species encountered included the state threatened *Schoenoplectus hallii* (A. Gray) S. G. Sm. (Hall's bulrush), and the state and federally threatened *Boltonia decurrens* (Torr. & Gray) Wood (decurrent false aster), the endangered *Schoenoplectus purshiana* (Fern.) M. T. Strong (Pursh's bulrush), and *Fimbristylis vahlii* (Lam.) Link (Vahl's fimbry) (IESPB 2020). The continued re-emergence of these species during wet years suggests their persistence in the soil seed bank (Van der Valk and Davis 1978; McClain *et al.* 1997; Phillippe *et al.* 2011).

At Sand Prairie-Scrub Oak Nature Preserve, 4 km west of Kilbourne in Mason County, there was a sizeable sand pond prior to the lowering of the water table, principally by the continued use of central pivot irrigation systems on land surrounding the preserve. Presently, water rarely accumulates in this stabilized blowout (McClain *et al.* 2008c). In contrast, a sand pond that commonly retains water in the spring and early summer of most years is located at Shick Shack Sand Pond Nature Preserve, located about 6 kms south of Bluff City in Cass County, Illinois (SE1/4 S9 T17N R11W). The majority of this preserve is dominated by degraded second growth upland, dry-mesic oak forest which surrounds a sand pond of about 1.5 ha (McFall and Karnes 1995). We observed that the vegetation of the pond was in three zones. The shrub zone, at the outer edge, was dominated by *Cephalanthus occidentalis* L. (buttonbush), *Salix interior* Rowlee (sandbar willow), *S. nigra* Marsh. (black willow), and *Sambucus canadensis* L. (common elderberry). The *Phalaris arundinacea* L. (reed canary grass) zone was next, with the associate *Persicaria lapathifolia* (L.) S. F. Gray (pale smartweed) being common and scattered. The center of the nearly dry pond was dominated by the mixed herbaceous zone with wetland species that commonly occur as emergents in shallow water.

Sand Seep

Seep communities occur in areas with saturated soil caused by groundwater reaching the surface in a diffuse flow (White and Madany 1978). Gates (1911) was first to describe a series of seep communities south of Havana, Illinois. The only seeps of high natural quality found during the present study, are located along White Oak Creek about 6 kms south of Havana, Mason County, Illinois (NW1/4 S23 T21N R9W). At this site numerous small seeps were located along both sides of White Oak Creek on a sandy terrace about 1500 m east of the Illinois River. The largest seep was nearly 125 m long, varied in width from 1 to 8 m, and was in an open area with nearly continuous sunlight throughout the day. The remaining seeps were smaller with the largest approximately 100 m long, 1 to 10 m wide, and shaded nearly the entire day (McClain *et al.* 2008a).

In the seep community in full sunlight, the perennial vine *Apios americana* Medic. (groundnut) was dominant [IV of 31.5 (possible 200)]. The species *Impatiens capensis* Meerb. (spotted touch-me-not), *Leersia oryzoides* (L.) Swartz (rice cut grass), *Decodon verticillatus* (L.) Ell. (swamp loosestrife), *Saururus cernuus* L. (lizard's-tail) and *Pilea pumila* (L.) Gray (clearweed) followed in importance. In the shaded seep *Symplocarpus foetidus* (L.) Nutt. (skunk cabbage) dominated (IV of 70.2), with *Impatiens capensis* and *Saururus cernuus* following in importance. The sunny seep plant community contained 23 species in the plots while only 19 were recorded for the shaded seep, with 12 common to both seeps (McClain *et al.* 2008a). Gates (1911) reported the state endangered *Mimulus glabratus* HBK. (yellow monkey-flower) and the state threatened *Veronica scutellata* L. (marsh speedwell) from this site, but neither were observed during our study (IESPB 2020).

Tall Shrub Fen

Dominated by tall shrubs, this fen community is on gently sloping ground in a lens of heavy peat soil with calcareous seepage, surrounded by sand deposits. It is located at the eastern edge of an *Acer saccharinum* L. (silver maple) wet floodplain forest of the Illinois River about 3 kms south of Spring Bay, Illinois (McFall and Karnes 1995). Presently, this tall shrub fen, located in Spring Bay Nature Preserve, Woodford County, Illinois (NW1/4 S23 T27N R4W), is the only tall shrub fen known in Illinois (Arnold 1970; Murphy et al 2009, 2021).

A few trees were growing in the fen with *Acer saccharinum* and *Fraxinus lanceolata* Borkh. (green ash), most less than 25 cm dbh. Shrubs were the dominant feature of the fen, averaging 5,975 stems/ha, the most important being *Ribes americanum* Mill. (wild black current), *Viburnum lentago* L. (nannyberry), *Cornus sericea* L. var. *sericea* (red-osier dogwood), and *Toxicodendron vernix* (L.) Kuntze (poison sumac). The most common species in the ground layer plots were *Apios americana* (IV of 27.62) followed by *Symplocarpus foetidus, Impatiens capensis*, *Aster firmus* Nees (swamp aster), *Sagittaria latifolia* Willd. (common arrowhead), and *Ribes americanum*. Of the 53 species encountered in the plots, three were non-native: *Lysimachia vulgaris* L. (loosestrife), *L. nummularia* L. (moneywort), and *Mentha* x *piperita* L. (peppermint) (Murphy *et al.* 2021). The state endangered *Cypripedium reginae* Walt. (showy lady's-slipper), and the state threatened *Boltonia decurrens* and *Filipendula rubra* (Hill) Robins. (Queen-of-the-prairie) have been reported from this fen community (IESPB 2020; Murphy *et al.*, 2009, 2021).

Sedge Meadow

This wetland community occurs on a deep, acid soil with a dark A horizon. Rare in the Illinois River sand deposits, the only extensive example occurs at Matanzas Prairie Nature Preserve about 2 kms north of Bath, Mason County, Illinois (NE1/4 S4 T20N R9W). In this community surface water was present during the winter and spring. This community is dominated by large tussocks of *Carex stricta* Lam. (IV of 66.6) with *Calamagrostis canadensis* (Michx.) P. Beauv. (bluejoint grass), and *Rosa palustris* Marsh. (swamp rose) ranking second and third in importance (Feist *et al.* 2008). Other common species include *Boehmeria cylindrica* (L.) Sw. (false nettle), *Tracaulon sagittatum* (L.) Small (tear thumb), *Thelypteris palustris* Schott. (marsh fern), *Doellingeria umbellata* (Mill.) Nees (flat-topped aster), and *Lycopus virginicus* L. (bugleweed). Colonies of *Rosa palustris* were common throughout the sedge meadow, accounting for nearly one quarter of the entire cover. This sedge meadow is occasionally burned which causes temporary, but dramatic, shifts in species composition (Feist *et al.* 2008).

Sand Prairie

This community type is dominated by grasses and occurs on course-textured sand and sandy loam soils. A few trees may be present, but less than 10% of the area has a tree canopy (White and Madany 1978). Prairie bunchgrasses dominate, but forbs occupy open spaces between these grasses. Generally, the drier the site, the less developed the soil A horizon, being essentially non-existent on dry sites to well-developed in mesic areas. Based on the original Government General Land Office survey records, Rodgers and Anderson (1979) determined that sand prairies dominated the sand deposits of Mason County, Illinois. On these prairies, trees were rare and averaged about 0.26 trees/ha and a basal area of 0.02 m^2/ha.

-*Dry Sand Prairie*: Gleason (1910) was the first to quantify the species composition of the Mixed Consocies of the Bunch-Grass Association in Illinois which corresponds to the dry sand prairie community of White and Madany (1978). As described by Gleason (1910), this association is dominated by native bunchgrasses with the remaining species restricted to areas of bare soil (sand) between bunchgrasses. These "secondary species" were divided into ecological groups based on their habit and structure: (1) large perennials and shrubs that competed with the bunchgrasses; (2) mat-plants, such as *Opuntia humifusa* (Raf.) Raf. (common prickly pear); (3) interstitial herbs that were mostly annuals and restricted to bare sand between the bunchgrasses; and (4) parasitic herbs. This community, in the absence of recurring fire, develops into a dry sand savanna community, and ultimately sand forest.

We studied five mature dry sand prairie communities in the Illinois River sand deposits, all from nature preserves and other state-owned lands in Mason County. These included Long Branch Nature Preserve (Phillippe *et al.* 2004), Henry Allan Gleason Nature Preserve (McClain *et al.* 2005), Sand Prairie-Scrub Oak Nature Preserve (McClain *et al.* 2008c), and Sand Ridge State Forest where two small dry sand prairie inclusions were surveyed, the 4 ha Burns Sand Prairie and the 2.4 ha Quiver Sand Prairie (Marcum *et al.* 2013; Phillippe *et al.* 2017).

None of the study sites showed indications of past disturbance except for a few paths, occasional tracks from off-road-vehicles, and animal borrows. All sites were dominated by *Schizachyrium scoparium* (Michx.) Nash (little bluestem). This bunchgrass commonly formed dense mats through which few other species grew, were mostly 20-60 cm across, and nearly circular in outline. Some of the larger clumps had centers that had died, and no other species were found growing in these centers. A typical example of this community type is located at Henry Allan Gleason Nature Preserve in northwestern Mason County, just southeast of the town of Goofy Ridge, Illinois. Dominated by a 20-meter-tall sand dune, commonly referred to as Devils Tower, this preserve was heavily disturbed at the time of dedication in 1970. The dune is commonly mentioned by Dr. Henry Allan Gleason in his memoirs, who made field trips to the sand region with students from the University of Illinois.

The dry sand prairie sampled is located on the east slope of Devils Tower, at the entrance to the preserve (SE1/4 S6 T22N R7W). Only 17 species were encountered in the study plots of this dry sand prairie remnant. The small size (about 1 ha), along with foot traffic and animal burrows, has resulted in some disturbances, but the prairie still contains species commonly associated with dry sand prairies (McClain *et al.* 2005). *Schizachyrium scoparium* (IV of 84.6) was the leading dominant, while *Tephrosia virginiana* (L.) Pers. (goat's-rue), *Opuntia humifusa, Ambrosia psilostachya* DC. (western ragweed) and *Dichanthelium villosissimum* (Nash) Frechm. (hairy panic grass) followed in importance. On this small prairie Fulk and Ebinger (1999) and Tucker *et al.* (2014) recorded the plant species encountered on the numerous small animal mounds created by foraging plains pocket gophers (*Geomys bursarius*) and badgers (*Taxidea taxus*). The few plants encountered on these mounds were small annuals, though seedings of a few perennials were also present, and a few perennials had growth through these mounds.

-*Late Successional Dry Sand Prairie:* Based on aerial photographs from 1939 and later years, it was possible to determine when many agricultural fields were abandoned in the nature preserves of the Illinois River sand deposits. At Sand Prairie-Scrub Oak Nature Preserve, a 60-year-old successional field, abandoned in the early 1940's, was surveyed in 2000 by McClain *et al.* (2008c) (SE1/4 S14 T20N R9W). A total of 20 native herbaceous species were encountered in the study plots. *Eragrostis trichodes* (Nutt.) Wood (thread love grass) dominated (IV of 51.2) but was absent in mature sand prairies on this preserve. This field contained many taxa commonly associated with mature sand prairies. Four of the top five species in importance by rank (*Schizachyrium scoparium, Ambrosia psilostachya, Dichanthelium villosissimum*, and *Opuntia humifusa*) are common components of mature dry sand prairies. Also, a disturbed dry sand prairie of unknown age, located on Devils Tower at Henry Allan Gleason Nature Preserve, surveyed in 2000 (McClain *et al.* 2005), has a very similar floristic composition (SE1/4 S6 T22N R7W).

-*Early Successional Dry Sand Prairie:* Successional fields 30 to 40 years of age are relatively common in the Illinois River sand deposits. At Sand Prairie-Scrub Oak Nature Preserve a 30-year-old successional field was surveyed in 2000 (McClain *et al.* 2008c) (NE1/4 NE1/4 S14 T20N R9W). This field, taken-out of cultivation when the preserve was purchased in 1969, was dominated by *Eragrostis trichodes* (IV of 97.4), followed in importance by *Strophostyles helvula* (L.) Ell. (wild bean), *Monarda punctata* L. (horsemint), *Eragrostis spectabilis* (Pursh) Steud. (tumble-grass), and *Paspalum bushii* Nash (hairy bead grass). Three dominants associated with mature dry sand prairie, *Schizachyrium scoparium*, *Ambrosia psilostachya,* and *Tephrosia virginiana* were not encountered while *Dichanthelium villosissimum* and *Opuntia humifusa* were rare.

-*Blow-Out Community:* Early studies suggested that blow-out communities were extremely common because of over-grazing and farming practices (Hart and Gleason 1907; Gleason 1910; Vestal 1913). Since the establishment of nature preserves in the Illinois sand deposits during the 1970's, most blow-outs became stabilized with successional vegetation. One large blow-out at Henry Allan Gleason Nature Preserve on the west flank of Devils Tower was surveyed (SE1/4 S6 T22N R7W) (McClain *et al.* 2005). In this community the vegetation was widely scattered, and bare ground and litter averaged 83.75% of the area. Only 12 species were encountered, with 8 species in the plots: *Aristida tuber-*

culosa Nutt. (needle grass) was the dominant species (IV of 95.5), followed by *Cyperus grayoides* Mohlenbr. (sand prairie flatsedge) and *Diodia teres* Walt. (rough buttonweed).

The Illinois threatened species *Cyperus grayoides* is a common associate of dry sand prairie blow-out communities at Long Branch Nature Preserve, Sand Prairie-Scrub Oak Nature Preserve, and Burns Sand Prairie at Sand Ridge State Forest (Phillippe *et al.* 2011). Also, in and around blow-outs on Devils Tower at Henry Allan Gleason Nature Preserve, the Illinois endangered *Lesquerella ludoviciana* (Nutt.) S. Wats. (silvery bladderpod) [now *Physaria ludoviciana* (Nutt.) O'Kane & Al-Shehbaz] is common. This western species occurs at its most easterly location here (Claerbout *et al.* 2007; Phillippe *et al.* 2011; Grant et al 2012). Presently, three populations of silvery bladderpod are known to occur in the preserve (McClain *et al.* 2005).

-*Wet-Mesic Sand Prairie*: This community occurs on a deep, acid, sandy soil with a dark A horizon. Water is present for short periods, particularly in winter and early spring (White and Madany 1978). Wet-mesic sand prairies are rare in the Illinois River sand deposits, the only example known to us is at Matanzas Prairie Nature Preserve about 2 kms north of Bath, Mason County, Illinois (NE1/4 S4 T20N R9W), and is not of high-quality. In a 1999 survey by Feist *et al.* (2008) this wet-mesic sand prairie was dominated by S*olidago canadensis* L. (Canada goldenrod, IV of 34.2), followed by *Andropogon gerardii* Vitman (big bluestem), *Carex stricta*, and the non-native grass *Poa pratensis* L. (Kentucky bluegrass) that was found throughout much of the prairie with a frequency of 68%. Other common species included *Euthamia graminifolia* (L.) Nutt. (grass-leaved goldenrod), *Fragaria virginiana* Duchesne (wild strawberry), *Rubus flagellaris* Willd. (common dewberry), *Vernonia missurica* Raf. (Missouri ironweed), *Potentilla simplex* Michx. (common cinquefoil), and *Sorghastrum nutans* (L.) Nash (Indian grass). A total of 92 taxa were found within the boundary of the wet-mesic sand prairie. In this prairie woody invasion is common with *Cornus drummondii* C.A. Mey. (rough-leaved dogwood), *C. obliqua* Raf. (pale dogwood), *Rosa palustris*, and *Salix discolor* Muhl. (pussy willow), along with the remnants of a 2-ha thicket dominated by *Betula nigra* L. (river birch), which has been greatly decreased in size by occasional prescribed burns (Uhlarik *et al.* 1990).

Dry Gravel Prairie

Located within the Illinois River sand deposits, this community, found on gravel soils with little organic material, is now rare in the Illinois River sand deposits. The only good quality example is located at Manito Prairie Nature Preserve about 12 kms southwest of Pekin, Tazewell County, Illinois (SW1/4 S15 T24N R6W) (McFall 1984; McClain *et al.* 2004). Gravel prairies were more common in pre-settlement times on the slopes of gravel terraces along the Illinois River, particularly north of present-day Peoria, Illinois. Most have been destroyed by excessive grazing, cultivation, and surface mining for gravel.

In a 2002 survey by McClain *et al.* (2004), this gravel prairie was dominated by the bunchgrass *Schizachyrium scoparium* (IV of 61.8) that was more than four times as abundant as the next most important species, *Dichanthelium oligosanthes* (Schult.) Gould (panic grass) with an IV of 12.3. Other native grasses included *Sorghastrum nutans, Sporobolus clandestinus* (Biehler) Hitchc. (dropseed), and *Bouteloua curtipendula* (Michx.) Torr. (side-oats grama), along with a small amount of *B. hirsuta* Lag. (grama grass). Common forbs included *Dalea purpurea* Vent. (purple prairie clover) followed by *Echinacea pallida* (Nutt.) Nutt. (pale coneflower), *Ambrosia psilostachya, Opuntia humifusa, Lespedeza capitata* Michx. (round-headed bush clover), *Chrysopsis camporum* Greene (prairie golden aster), and *Senecio plattensis* Nutt. (prairie groundsel).

The state threatened *Besseya bullii* (Eat.) Rydb. (kitten tails), the state endangered *Astragalus tennesseensis* Gray (Tennessee milk vetch), and the federally threatened, *Tetraneuris herbacea* Greene (lakeside daisy) (IESPB 2020) were found on the preserve. Lakeside daisy disappeared from Manito Prairie in early 1960s but was reintroduced at three location in 1988 (McClain and Ebinger 2008; Phillippe *et al.* 2011). We located one flowering and 63 non-flowering individuals at one of the reintroduction sites in 2003. Long-term survival of this species at Manito Prairie Nature Preserve appeared unlikely as it has not been found at this preserve since our report in 2004 (IDNR, Michelle Simone, personal communication). Presently, the only known location for *Astragalus tennesseensis* in Illinois is at Manito Prairie Nature Preserve (McClain and Ebinger 2003).

Sand Savanna

Common in pre-settlement times, sand savannas are usually associated with dune and swale topography and other natural fire breaks throughout the Illinois River sand deposits. These fire breaks limit the frequency and severity of fires, allowing the establishment of fire-resistant, thick-barked tree species (Anderson 1991). These two-layered communities have a nearly continuous ground layer composed mostly of prairie bunchgrasses and forbs along with scattered prairie shrubs. The tree canopy has a cover of 10% to 40% composed of broad-canopied trees usually with low branches that may extend to near ground level, depending on fire frequency and intensity. Based on original Government General Land Office Survey records, Rodgers and Anderson (1979) estimated that in the 1820s, 67.7% of Mason County was sand prairie, 14.4% sand savanna, 4.3% open sand forest, 9.0% closed sand forest, and 4.6% lakes and swamps.

Two sand savanna community types existed in presettlement times in the Illinois River sand deposits, the result of moisture requirements: dry sand savanna and dry-mesic sand savanna (White and Madany 1978). In dry sand savannas, *Quercus velutina* Lam. (black oak) was commonly the only tree species found in the canopy, and the soil lacked, or had a poorly developed A horizon. Dry-mesic sand savannas, in contrast, though usually dominated by *Q. velutina*, contain some *Q. alba* L. (white oak) and/or other tree species reaching the canopy, and the soil A horizon was better developed being darker and thicker. Also, the topographic position of these two savanna types differed; dry sand savannas were usually on the upper slopes and ridges of sand dunes; while dry-mesic sand savannas were mostly restricted to the lower dune slopes and sandy terraces of rivers and large streams which afford some protection from prairie fires. At the present time, both dry and dry-mesic sand savannas are essentially absent from the Illinois River sand deposits mostly due to fire suppression since early settlement-times (Rodgers and Anderson 1979). These two communities, over time, grew into closed forests, and in the process lost the characteristic open canopy structure and prairie understory, with soil tending to develop a deeper and darker A horizon.

-*Dry Sand Savanna*: Remnants of dry sand savannas are common in the Illinois River sand deposits. All, however, have been degraded by logging, grazing, fire suppression, and invasion by woody shrubs and non-native species (Anderson and Brown 1986; Anderson 1991; Abrams 1992; McClain and Elzinga 1994). The prairie bunchgrasses of the ground layer are mostly gone, as are most of the prairie forbs, being replaced by shade-tolerant herbaceous species associated with closed-canopy forests. These species thrive with less light and more moisture and add to the litter layer that is not regularly removed by fire. Also, the canopy is multi-layered, more younger trees are growing taller and straighter, their lower branches self-pruning, and underneath the canopy is a subcanopy composed of small trees and tall shrubs. The forest is becoming filled! It will become a thicket in the subcanopy layers, with the lack of fire and/or grazing (McClain *et al.* 2021).

Four dry sand savanna communities that, over time, developed into closed dry sand forests, have been studied in the Illinois River sand deposits, all located on state-owned lands in Mason County. All have closed canopies with large black oaks dominating the overstory, a developed subcanopy, and a ground layer lacking most prairie grasses and forbs. These include: Bishops Woods at the southern part of Sand Ridge State Forest (Jenkins *et al.* 1991), Barkhausen Woods Conservation Area (Coates *et al.* 1992), Sand Prairie-Scrub Oak Nature Preserve (McClain *et al.* 2002), and an area near the central part of Sand Ridge State Forest (Phillippe *et al.* 2013).

In these closed forests, *Quercus velutina* is the dominant tree species and the only taxon that has individuals in the larger diameter classes. Many larger individuals are missing their lower branches, and dead snags and branch scars are obvious, an indication of their previous open-grown structure. The black oaks in the lower diameter classes are tall and straight, with a narrower canopy and trunks that lack lower branches. Also present are scattered individuals of more mesic species such as *Prunus serotina* Ehrh. (wild black cherry), *Carya tomentosa* (Poir.) Nutt. (mockernut hickory), *Diospyros virginiana* L. (persimmon), *Ulmus americana* L. (American elm), and *Tilia americana* L. (basswood) along with an occasional non-native tree species [*Catalpa speciosa* Warder (catalpa) and *Morus alba* L. (white mulberry)].

Degraded dry sand savannas that are presently forests due to fire suppression are the dominant community of ridges and upper slopes on the large, stabilized dunes at Sand Ridge State Forest, Mason County (Phillippe *et al*. 2013). Based on an analysis of 1939 aerial photographs, approximately 50.18% of the present area of Sand Ridge State Forest was covered by trees and large shrubs. In the absence of fire, canopy cover increased dramatically in the 1957 aerial photographs to 68.96%, in 1969 to 78.66%, in 1988 to 88.08%, while in 1998 canopy cover was 89.50%. As a result of fire suppression, in about 70 years the sand savanna, covering most of Sand Ridge State Forest, became a closed forest (Phillippe *et al.* 2013).

In the dry sand savanna community surveyed in 2004 at Sand Ridge State Forest, 11 tree species were encountered (Ebinger *et al.* 2007; Phillippe *et al.* 2013). *Quercus velutina* dominate all diameter classes, accounting for 65% of the stems/ha, and is the only species with trunks greater than 60 cm dbh. This species had an IV of 143.5, averaged 321.1 stems/ha, averaged 23.6 cm dbh, and accounted for 78.1% of the total basal area. *Quercus marilandica* Muench. (blackjack oak) (IV of 34.7) ranked second in importance, followed by the adventive *Pinus strobus* L. (white pine), and *Carya texana* Buckl. (black hickory). The woody understory averaged 15,200 seedlings/ha, 1,775 small saplings/ha, and 295 large saplings/ha. Because of the relatively few saplings, the woody understory was fairly open. Few prairie grasses were encountered though many prairie forbs were present in low numbers (Maier 1976; Marcum *et al.* 2013).

-*Dry-mesic Sand Savanna*: Sand savannas associated with lower dunes slopes, ravines, and sandy river terraces are more mesic than dry sand savannas (White and Madany 1978). In these savannas *Quercus velutina* was present, but more mesic tree species, particularly *Quercus alba,* were canopy members. Other species were present in low numbers, including *Celtis occidentalis* L. (hackberry), *Juglans nigra* L. (black walnut), Sassafras *albidum* (Nutt.) Nees (sassafras), and *Ulmus americana*. Due to the lower topographic position, there was usually some development of a soil A horizon; some mesic ground layer prairie species were present; and some prairie grasses commonly exceeded 1 m in height. Due to lack of fires and non-native species encroachment good quality examples of dry-mesic sand savannas no longer exist in the Illinois River sand deposits.

One former degraded dry-mesic sand savanna that presently is a dry-mesic sand forest was studied in 2004 (McClain *et al.* 2008b). Located in the Speckman-Stelter Woods Land and Water Reserve, this woodlot is about 6 kms south of Havana (NW1/4 S23 T21N R9W) (Ebinger 2005; Ebinger *et al.* 2007; McClain *et al.* 2008b). About 2 ha in size, this woodlot is located on a sandy terrace about 1500 m east of the Illinois River. *Quercus alba* dominates the larger diameter classes with an IV of 144.2, and an average diameter of 53.4 cm. Most of the larger *Q. alba* had open-grown canopies with large branches or branch scars within 4 m of the ground. *Quercus velutina*, also restricted to the larger diameter classes, was second in IV (12.7) and had an average diameter of 71.3 cm. The remaining species, mostly in the 10-29 cm diameter classes, were recent encroachments, three being non-native. The density of tree seedlings, shrubs, and woody vines was high, totaling 19,000 individuals/ha, small saplings averaged 2,250 stems/ha, and large saplings totaled 1,370 stems/ha. *Sassafras albidum* dominated the seedling and sapling categories with 4300 seedlings/ha, 1600 small saplings/ha, and 545 large saplings/ha while *Celtis occidentalis* was second with 1700 seedlings/ha, but few saplings. Oak seedlings were next, being fairly common, but no oak saplings were recorded, and no oaks were found in the 10-39 cm diameter classes.

According to Lerczak (2000), Ms. Stelter, the owner of the property, recalled her great grandfather saying that it was possible to drive a wagon through the woods in the 1840s, an indication of its openness. Also mentioned was the presence of many oak grubs. Grubs are usually associated with the nearly annual prairie fires that burned extensive tracts of grassland, top-killing many of the smaller oak and hickory trees. These plants, despite the prairie fires, developed large, gnarled root systems that were often many years old despite their small stature. The cessation of prairie fires allowed these "grubs" to quickly develop into small trees. The present appearance of White Oak Creek Woods, compared to 150 years ago, is probably due to a reduced fire frequency followed by a total absence of fire in recent decades (Taft 1997; McClain *et al.* 2021).

Dry Sand Forest

Forests are generally defined as communities dominated by trees and have nearly closed overstories with more than 80% canopy cover (Nuzzo 1986; White and Madany 1978). The soil commonly has a dark A horizon from accumulated leaf litter, the ground cover may have some prairie species, but native shade-tolerant forest species are common. Dry sand forests are associated with dune and swale topography and other natural fire breaks that greatly limited the frequency and severity of fires. Post-European settlement fire exclusion in the Illinois River sand deposits has increased the acreage of sand forest at the expense of sand savannas and open sand forests (Anderson and Brown 1986; Anderson 1991; McClain *et al.* 2021).

According to Rodgers and Anderson (1979) presettlement closed sand forests were relatively common in Mason County and accounted for about 9.0% of the vegetation. They estimated that tree density averaged 263 stems/ha in these forests, while basal area averaged 29 m^2/ha. Using Government Land Office survey records they found that these sand forests were mostly restricted to areas along the Illinois River and areas of extensive dunes in the northern and central parts of the county. Present-day dry sand forests (80-100% canopy cover), that in presettlement times were probably sand savannas (10 to 40% canopy cover) or open sand forest (40 to 80% canopy cover), have been studied in Mason County: Bishop's Woods Natural Area (Jenkins *et al.* 1991), Barkhausen Woods Natural Area (Coates *et al.* 1992), and Tomlin Timber Nature Preserve (Phillippe *et al.* 2009).

Tomlin Timber Nature Preserve is located about 2 kms southwest of Easton, Mason County, Illinois (SW1/4 S11 T20N R7W). When surveyed by the Illinois Natural Areas Inventory (White 1978), the owner indicated that the woods had been selectively logged 50 to 60 years ago, but never grazed. Don McFall (Illinois Department of Natural Resources, personal communication) mentions that he first walked through the woods in the early 1980s, and there was a fairly dense woody understory and a number of large dead black oaks. The preserve was dedicated as a Nature Preserve in 1987 (McFall and Karnes 1995).

Surveyed in 2003, 19 tree species were present in the overstory of Tomlin Timber. *Sassafras albidum* dominated with an importance value of 54.9 (possible 200), an average dbh of 24.4 cm, with most individuals in the 10-39 cm diameter classes (Phillippe *et al.* 2009). *Quercus velutina* (IV of 38.5), with an average dbh of 62.7 cm, dominated the 50+ cm diameter classes. Other common species included *Carya texana*, *Celtis occidentalis*, *Prunus serotina*, *Ulmus americana*, *Carya tomentosa*, *Ulmus rubra* Muhl. (slippery elm), and *Asimina triloba* (L.) Dunal (pawpaw). The woody understory was dense with 18,639 woody seedlings/ha, 4,862 small saplings/ha, and 1,222 large saplings/ha. Extensive colonies of *Asimina triloba* occurred throughout the preserve, averaging 4,028 seedlings/ha, 2,986 small saplings/ha, 854 large saplings/ha, along with 14.9 stems/ha that exceeded 10 cm dbh. The herbaceous understory was composed mostly of shade-tolerant forest species, 113 taxa being encountered including 24 non-native species. Tomlin Timber is another example of oaks being replaced by more mesic, thin-barked tree species due to a reduced fire frequency (Ebinger and McClain 1991; Taft 1997).

Tomlin Timber was part of an extensive dry open sand forest in pre-settlement times. Canopy closure and increased importance of mesic trees, resulting from fire suppression, has altered its structure. With canopy closure, shade-intolerant *Quercus velutina* could not effectively recruit. *Sassafras albidum*, a fire-sensitive but relatively shade-tolerant species, became the dominant understory species, entered the canopy, and now has the highest importance value. Though the growth of *Sassafras albidum* is not rapid, this species can reproduce by root suckers, probably the reason for the relatively rapid increase of this species since European settlement.

CONCLUSIONS

This review documents many of the changes that have occurred within some of the plant communities of the sand deposits in the Illinois River Valley since early European settlement. Grasslands have a long and dynamic history in North America since the Miocene, and fire is now considered the primary reason for their modern origin and in the persistence of the Midwestern Tallgrass Prairie (McClain *et al.* 2021). A reduction in the extent and frequency of wild fires, with the increase in European settlement in the 1800s, resulted in the increase of forest at the expense of prairie. This decrease in fire frequency and extent resulted in the woody invasion of prairie and savanna with the resulting dominance of forest through the Midwestern Tallgrass Prairie. Also, more subtle changes have occurred during the past 150 years, like the lowering of the water table, which has eliminated many sand ponds and wetlands, and the more recent invasion of non-native species that decreased habitat availability for native species.

Plant communities are always in a state of flux and change with the passage of time. Human activities, over time, accelerated these changes, by preventing prairie fires, draining wetlands, cultivating, and home steading. This is now obvious with the change in structure and composition of the sand prairies and sand savannas that once covered most of the study area. These plant communities can rarely be found at the present time, and we looked very hard! Other than the few we have studied, other examples are relatively rare in the Illinois River Valley, and as far as we can tell, are mostly restricted to dedicated nature preserves. The few remaining outside of dedicated nature preserves are degraded remnants that are small with low species diversity. The tree part of these communities is still present, but usually with a greater density compared to the average in the 1800s. Parks, in and around small towns, and some large yards, still contain the tree component of large black and white oaks, including some with lower branches suggesting a former open community. The prairie understory, however, has been replaced by Kentucky bluegrass, crabgrass, fescue, and dandelions. To maintain these savanna and forest communities requires fire on a fairly regular basis. However, by studying the few remaining plant communities, we can usually infer their floristic composition and structure before European settlement.

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Past, Present, and Possible Future Trends with Climate Change in Illinois Forests

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Abstract: There have been dramatic changes to forest lands since the end of the last ice age, about 14,000 years before present, when boreal ecosystems were eventually replaced by deciduous forest and grassland. In Illinois at the time of Euro-American Settlement (circa 1820), forest lands, including fire-maintained woodlands and savannas, comprised about 42% of the land area. Habitat destruction, fire absence, livestock grazing, and infestations of non-native species have altered forests since the 1800s. Currently, forest land cover statewide is about 13.5%, mostly (83%) in private ownership and predominately (68%) classified as oak-hickory cover type. Further modifications can be expected due to climate change, predicted for Illinois over the next 100 years to include warmer winter temperatures, warmer and wetter springs, and hotter, drier summers.

Models predicting potential futures for 113 tree species as a response to climate change over the next 100 years were generated for ten primary Illinois ecoregions. Results indicate that there are likely to be increases in habitat suitability and capability for some species and decreased habitat suitability and capability for others with variability across ecoregions. Many species demonstrate differential responses to changing climate from north to south in the state. The dominant species in the oak-hickory cover type generally are projected to have fair to good capabilities, with some notable exceptions; however, *Acer saccharum*, a competitor in many oak-hickory stands, also is projected to have fair to good capability. Dominant species in mesic upland and bottomland forests include a rich variety of species about evenly split between those with fair-to-good capabilities and those expected to have poor capability. Potential 'New Habitat' and 'Migrate' species also are identified. New Habitat species are those that have potential habitat appearing in the state within 100 years; Migrate species have some potential for natural distribution to the state within 100 years and could be considered as candidates for assisted migration northward. Considerations for conservation and management of forest lands are discussed.

Introduction

The possible effects of climate change on vegetation are topics of current interest as they have implications for efforts to sustain biodiversity and conservation planning and design. Significant alterations over time are part of the vegetation history of Illinois. Here we focus on forest trends. To provide context for possible future forests, we provide a summary review of past forest trends in Illinois (adapted from Taft *et al.* 2009) with updated current status. We then present potential future trends for tree species across the state resulting from ongoing and anticipated future changes in climate over the next 100 years, which is expected to include increasing mean-annual temperature and precipitation as well as increased likelihood of summer droughts (Pryor *et al.* 2014; Wuebbles *et al.* 2021). Projected trends among tree species are the outcome of multivariate models developed for the eastern United States (Iverson *et al.* 2019a, 2019b), modified to apply specifically to the geographic context of Illinois ecoregions (Figure 1).

Past, Present, and Future Forests

Changes in vegetation composition and structure can be measured over a wide range of time scales, from seasonally to over thousands of years. Such changes inform many aspects of environmental condition. Illinois occurs within a temperate climate zone where a wide range of vegetation changes appear seasonally. When examining vegetation over longer time spans, from a few

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Figure 1. Illinois ecoregions used in this analysis.

years to decades, composition and structure can vary greatly due to a variety of extrinsic factors, depending on their magnitude and duration (e.g., drought, flooding, grazing, fire, fire absence, invasive species), which in turn favor species adapted to, or more tolerant of, those conditions. When examining changes over even longer time spans, such as since the last glacial period about 14,000 years ago, far greater differences have occurred with sequential wholesale conversions of different vegetation types (King 1981). These more dramatic alterations largely correspond to changes in climate.

Post-Pleistocene Trends

The last glacial episode, known as Wisconsinan glaciation, covered the northeastern quarter of Illinois with a thick layer of ice from about 30,000 to 14,000 years ago (Killey 2007). Vegetational changes since that time throughout Illinois included, in places, a brief tundra phase followed by a period of domination by spruce and fir and then spruce and pine forests (Voss 1934; Boggess and Geiss 1968; King 1981). There is fossil pollen evidence of spruce woodland and tundra occurring in central Illinois (King 1981) and even in southern Illinois (Voss 1934) during the late Pleistocene. These are vegetation types now limited to boreal zones hundreds of kilometers north of the state. This boreal phase lasted a few thousand years but by 9,000 years before present (B.P.), with the development of a warming cycle known as the xerothermic (Sears 1942), deciduous forest began to enter the region. By about 8,300 years B.P., forests were dominated by species of oak and hickory (Anderson 1991) and prairie species began to invade (King 1981) forming part of a Prairie Peninsula extending east of the Rocky Mountains to Ohio (Transeau 1935). Although there is regional variation, the period from about 8,000 years B.P. to 5,000 years B.P. included the emergence of savanna and open woodland habitats (Taft 1997; Anderson and Bowles 1998). Increased moisture in the southern portion of the prairie peninsula about 5,000 years B.P. resulted in an increase in forest in that region (King 1981). Since then and until the time of Euro-American settlement around 1820 to 1840, fire, including intentional burning by indigenous people, periodic droughts, and grazing animals helped maintain grassland, savanna, and open woodland habitats (Anderson 1970, 1983; Taft 1997).

Forests at the time of Euro-American settlement (circa 1820)

At the time of the first Euro-American settlements in Illinois, forest, woodland, and savanna covered about 6.2 million ha, or 42% of the land area (Szafoni *et al.* 2002). Large expanses of these wooded plant communities existed at the time of Euro-American settlement with the greatest concentrations in the western and southern regions (Figure 2). Characteristics of the landscape had great influence on forest distribution. Upland forests primarily were concentrated in areas of greater topographic relief such as the dissected terrain of riparian corridors where there was some, especially leeward, fire protection (Gleason 1913), while forested wetlands naturally occurred on poorly drained floodplains (Iverson 1988). About three-quarters of all forest cover in Illinois is associated with slopes greater than 4% (Anderson 1991), while most of the timbered land with slopes less than 4% are associated with floodplains or undissected low fertility soils in the Illinoian till plain located in the southern half of the state.

Forests at this time differed from most current stands by their exposure to occasional fires. Woodland habitats, intermediate in structure and composition between forest and savanna, were common and strongly dominated by oak species. Of the 20 oak species native to Illinois, many were and remain common in the overstory of upland woodlands and forests statewide, such

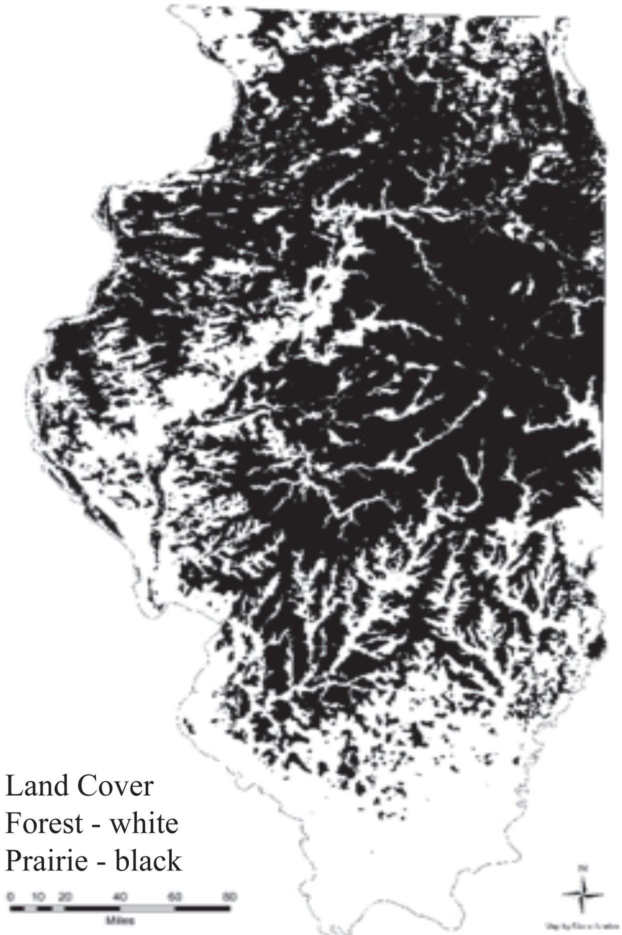

Figure 2. Prairie and forest land cover in Illinois during the early 1800s. From Szafoni *et al.* (2002).

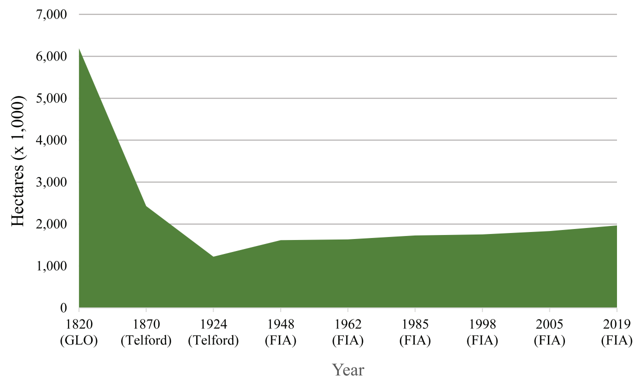

Figure 3. Trends for total forest area in Illinois from Government Land Office (GLO) surveys from about 1820 through current (2019) based on Forest Inventory and Analysis (FIA) data (USDA 2019a).

as *Quercus alba*, *Q. rubra*, *Q. velutina*, *Q. macrocarpa*, and *Q. muhlenbergii*, or regionally such as *Q. stellata*, *Q. marilandica*, and *Q. falcata*. Oaks greater than a few centimeters diameter are capable of enduring low intensity fires typical of woodlands, thereby favoring their past dominance and ecological significance. In contrast, species like *Acer saccharum* are favored in more closed and shaded forest stands and when young, tend to be fire sensitive. According to early surveyor records, *A. saccharum* was scarce in oak-hickory stands compared with modern forests (Ebinger 1986, 1997), supportive evidence that fire historically was a widespread and general phenomenon.

Forest Trends Since Settlement

Forest clearing, grazing by livestock, fire suppression, and infestations by non-native species have, to varying degrees, altered Illinois forests since the early 1800s. The extent of deforestation in Illinois can be deduced by the estimates of forest land cover in the 1800s and in periodic forest surveys beginning in 1924 (Telford 1926; Hahn 1987; Schmidt *et al.* 2000; Crocker *et al.* 2005; USDA 2019a). Following a period of intensive harvest, particularly from 1860 to 1900 (Iverson *et al.* 1989), forest area in Illinois reached its minimum extent in about 1920 with 1.22 million ha, 8.5% statewide coverage and just under a quarter of the pre-Euro-American settlement total. During the next 100 years, area of forest land cover increased to about 1.96 million ha (Figure 3), 13.5% statewide coverage, a linear annual rate of increase of about 7,400 ha (0.61%). This trend can be partially attributed to a reduction in cattle grazing and conversion of marginal cropland and pastures to tree cover. In some cases, trees now grow where once was prairie. Statewide forest land cover in 2000 included about 353,966 ha that was non-forest land cover in the early 1800s (Szafoni *et al.* 2009).

As a result of habitat fragmentation and intentional suppression, fire frequency has declined dramatically and, as a result, there has been a shift in native species composition characterized by increasing tree density and abundance of shade-tolerant and generally fire-intolerant species in forest and woodland understories, a phenomenon widespread throughout forests in the eastern U.S. termed mesophication (Abrams 2005; Nowacki and Abrams 2008). Consequently, fire-dependent savannas and open woodland habitats, with their characteristic rich diversity of ground-layer species, have become quite scarce (Nuzzo 1986; Noss *et al.* 1995; Taft 1997).

Current Status of Illinois Forests

Current forest area is just under a third of the pre-Euro-American settlement (circa 1820) extent (Figure 3). However, based on the qualitative criteria developed for the Illinois Natural Areas Inventory (White 1978),

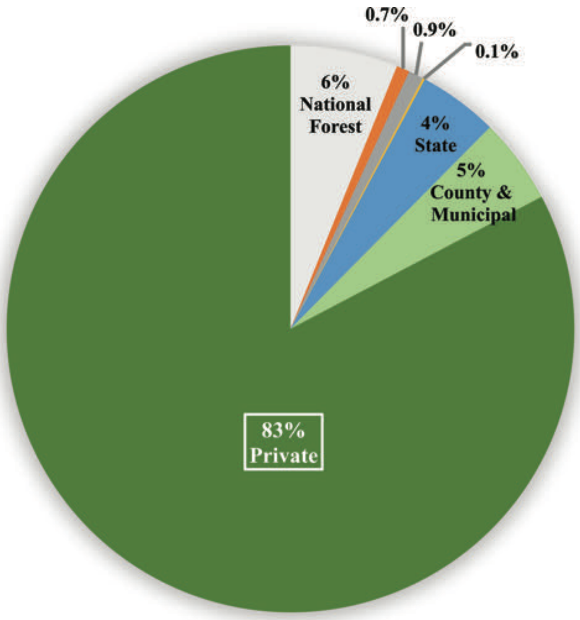

Figure 4. Percent of Illinois forest by ownership type. Minor ownership types (<1%) include U.S. Fish & Wildlife, Department of Defense, and other federal. From unpublished 2019 Forest Inventory and Analysis data (USDA 2019a).

only about 0.1% of the acreage at the time of settlement, and about 0.36% of remaining forests, persist in a condition relatively free of past habitat damage (IDNR 2008). Relevant to conservation efforts, most forest in Illinois occurs on private lands (83%) followed by federal (8%), local government (5%), and state (4%) land holdings (Figure 4). Of the current total forest and woodland area, most is classified as upland habitat and about 18% is bottomland forest and swamp (Suloway *et al.* 1992). Since 1985, forest stands classified as oak-hickory and elm-ash-soft maple-cottonwood, based on the canopy dominance of those species, have increased in area while stands classified as maple-beech-aspen have declined in area (Figure 5). Declining trends can be due to selective habitat destruction, reclassification, or both. Currently, most acreage is classified as oak-hickory (68%) followed by elm-ash-soft maple-cottonwood (23.9%) (Figure 6). However, in current forests, the proportion of oak-hickory forest types is much greater in the older age-class stands compared to younger age-class stands (Figure 7). As such, absence of fire and mesophication may be leading to the possibility of a general replacement of oaks in forest canopies by more shade-tolerant species (Nowacki and Abrams 2008). Simultaneously though, the changing climate will likely have a compounding influence on this outcome because droughty,

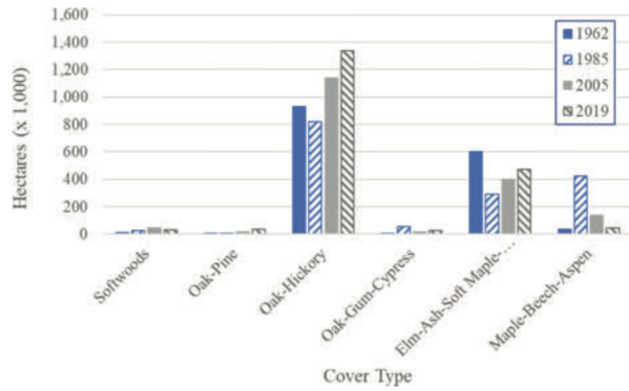

Figure 5. Trends in forest area in Illinois by type since 1962. From Taft *et al.* (2009) and unpublished 2019 Forest Inventory and Analysis data (USDA 2019a).

hotter climates tend to favor the oak species (Iverson *et al.* 2019c).

Future Climate-Related Effects on Illinois Tree Species

Over the next 100 years, forests will be shaped by the responses of tree species to climate change as mediated by local conditions, with effects varying among species and even individuals of the same species. Models predicting potential futures for tree species throughout the eastern U.S. have been generated by the Landscape Change Research Group of the Northern Institute of Applied Climate Science, USDA Forest Service (Iverson

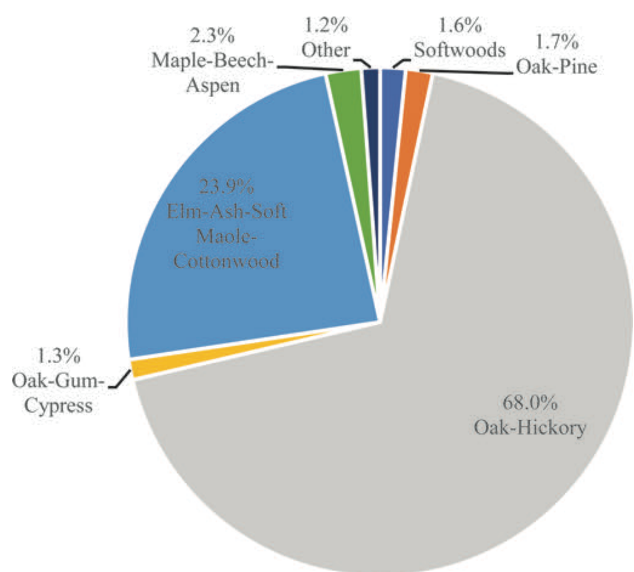

Figure 6. Percent area of Illinois forest land by type. From unpublished 2019 Forest Inventory and Analysis data (USDA 2019a).

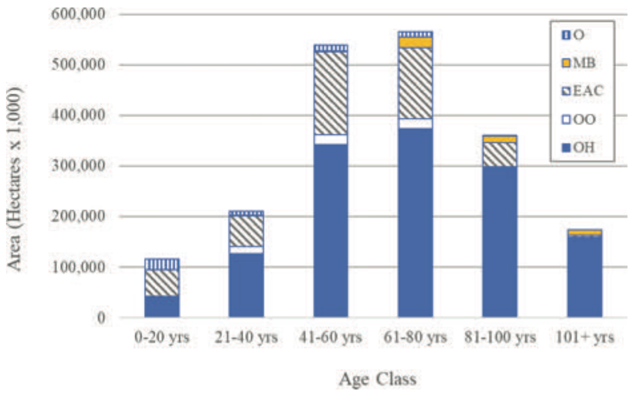

Figure 7. Distribution of forest type in Illinois by age class. Unpublished 2019 Forest Inventory and Analysis data (USDA 2019a). O = other, MB = maple-beech, EAC = elm, ash, cottonwood, OO = oak and other, OH = oak hickory.

et al. 2019a, b; Peters *et al.* 2019; Peters *et al.* 2020). To provide an assessment specific to Illinois, a new analysis was completed to summarize the potential tree species responses from these models for the primary ecoregions in the state (Figure 1). Our primary goals are to present the results of these models and how projected change will affect tree composition of Illinois forests and how conservation and management efforts can address these changes.

Methods

We used two models to estimate potential tree species response to the changing climate. The first, DISTRIB-II, provides an estimate of the distributional range of the species currently, based on statistical relationships between their known locations (from inventories) and a series of 45 climatic, soil, and topographic variables. Then, seven climatic variables were changed according to climate estimates for 2100, and the models re-run to show potential suitable habitat in the future for each species. The DISTRIB-II model runs at either a 1 0 ×10 km or 20×20 km grid, depending on the density of inventory plots, as it requires a minimum of three plots to assign an average abundance for each species in the cell (Peters *et al.* 2019). The second model, SHIFT, is a mechanistic model which uses species abundance output from DISTRIB-II along with current land cover information and generalized historic (Holocene) rates of migration of 50 km per century (if fully forested, proportionately less as forest cover diminishes) to spatially represent possible changes in actual distribution within the next 100 years. We refer to earlier citations for details on the models (Iverson *et al.* 2019a, b, Peters *et al.* 2019). These two models, when combined, provide estimates of not only where tree habitat may change in the future (DISTRIB-II), but also how much of the newly suitable habitat may be colonized within the next 100 years (SHIFT).

A primary data set required for these models is the US Forest Service's Forest Inventory and Analysis (FIA) data, with over 100,000 plots across the eastern US (USDA 2019a), including 1,861 plots in Illinois (Gray *et al.* 2012; Crocker *et al.* 2015). These plots are laid down across the state in proportion to the forest cover so that a map of forest cover (e.g., see Crocker el al 2015; Figure 2) also represents the density of forest plots. Another key data set is the projections of climate according to various scenarios of climate change by 2100. In this study, we present results according to the average outcome of three Global Climate Models (GCMs) with the Representative Concentration Pathway (RCP) at a relatively high level of emissions (RCP 8.5), where the earth's atmosphere is trending so far (Wuebbles *et al.* 2021).

These models were evaluated for each of 10 major ecoregions (Figure 1) recognized for Illinois (Cleland *et al.* 2007); however, two small ecoregions in southernmost Illinois, Coastal Plains-Loess and White and Black River Alluvial Plains, were combined for this analysis. To capture enough area to ensure robust statistical analysis, ecoregions less than 8,000 km^2 (Table 1) were buffered with enough area to achieve this minimum sample area, sometimes expanding into bordering states and often overlapping other Illinois ecoregions until the 8,000 km^2 threshold was exceeded (Figure 8).

These data were used to calculate abundance for each species found in each ecoregion, currently and potentially into the future (~2100). Here we present two key variables for each species in each ecoregion. The first is *FIAsum*, which provides an indication of over-all species importance within each ecoregion. For each species, a relative importance value was calculated, based equally on the average number of stems and basal area for all FIA plots within each 10×10 or 20×20 km cell; these importance values are then summed for all cells within each ecoregion. *FIAsum*, therefore, indicates the overall importance of a species in an ecoregion, reflecting not only the size and abundance of individual tree species but also total forest cover within the ecoregion. *Total FIAsum* (Appendix) is the sum of species importance across all ecoregions and is a measure of statewide importance based on FIA sample data. The second variable is capability (*Cap.*), a measure of species capacity, scaled 1-5 (very poor, poor, fair, good, very good), to cope or persist with the expected climatic changes based on its categories of current abundance, adaptability, and change class following projected climate change. As an example, for species currently abundant with high adaptability to the changing climate

Table 1: The nine primary ecoregions from Illinois, used in this analysis. Area is the km^2 of area used for analysis; a minimum of 8,000 km^2 was required such that several ecoregions were buffered until that minimum was reached. 231H and 234D were merged for this analysis.

CODE	PROVINCE	SECTION	AREA (km^2)	SECTNAME
222H	Midwest Broadleaf Forest	Central Till Plains-Beech-Maple	8,700	IL_222H
222K	Midwest Broadleaf Forest	Southwestern Great Lakes Morainal	22,721	IL_222K
222L	Midwest Broadleaf Forest	North Central U.S. Driftless and Escarpment	8,300	IL_222L
223A	Central Interior Broadleaf Forest	Ozark Highlands	8,500	IL_223A
223D	Central Interior Broadleaf Forest	Interior Low Plateau-Shawnee Hills	10,900	IL_223D
223G	Central Interior Broadleaf Forest	Central Till Plains-Oak Hickory	43,800	IL_223G
231H	Southeastern Mixed Forest	Coastal Plains-Loess	8,700	IL_231H/234D
234D	Lower Mississippi Riverine Forest	White and Black River Alluvial Plains	8,700	IL_231H/234D
251C	Prairie Parkland (Temperate)	Central Dissected Till Plains	47,900	IL_251C
251D	Prairie Parkland (Temperate)	Central Till Plains and Grand Prairies	69,500	IL_251D

(Matthews *et al.* 2011), and with estimates of increased suitable habitat at 2100, the 'very good' capability was assigned, with decreasing capability as the three variables diminish. Mean capability (*MeanCap*) is a measure across all ecoregions based on ecoregions of occurrence (not including when a species is absent within an ecoregion [Appendix]). A curiosity of the FIA database is that species found native in the state, such as *Pinus strobus*, *P. resinosa*, and *Robinia pseudoacacia*, that are also planted and adventive outside of their native Illinois ranges, are considered native wherever recorded and we did not try to untangle the differences.

Also reported under the capability variable, *Cap*, is a designation of 'New Habitat' and 'Migrate' for certain species (Appendix). 'New Habitat' species are those that, according to the DISTRIB-II model, are not known to be present according to FIA plot data but have potential habitat appearing by 2100. Importantly, this designation does not consider whether the species will get there by 2100, only that suitable habitat may appear there. 'Migrate' species, on the other hand, are species not reported from FIA sample data or modeled to be in the zone, but have some potential, according to the SHIFT model, to naturally migrate there within 100 years. Thus, these 'Migrate' species could be considered as good candidates for assisted migration (Prasad *et al.* 2016; Iverson *et al.* 2019a). Of course, managers would need to use their local knowledge of matching species and habitats for final species selections. The SHIFT model incorporates landscape heterogeneity of forest cover into the expected range extensions and includes the capability estimates for each species.

Botanical nomenclature for the tree species in this study follows the USDA Forest Inventory and Analysis (USDA 2019a). Common names for tree species can be found in the Appendix.

RESULTS

Species Richness and Importance

A total of 113 tree species were evaluated in this study including 94 species currently detected by FIA plots and 19 modeled to have habitat available by 2100 under climate change (RCP 8.5) (Appendix). Of those detected recently within the 1,861 FIA plots, 83 native species, four adventive species (native to North America but not Illinois), and seven introduced non-native species were recorded. Seven of the native species had inadequate sample data for capability modelling. Currently, according to *Total FIAsum*, the overall top species in the buffered state are *Quercus alba*, *Acer saccharum*, *Ulmus americana*, *Liriodendron tulipifera*, and *Q. velutina* (Appendix). Total forest land cover and, thus, sample area differs among ecoregions (Table 2). Consequently, there is a correlation between species counts and the number of plots available for this analysis. The three ecoregions with the least richness also have the fewest plots because of the relatively small total area evaluated (222L and 222H, Table 1)

Table 2: Summary of species numbers and capability classes by Illinois ecoregion. Also shown is the land cover percentages and number of FIA plots by ecoregion. FIA =Forest Inventory and Analysis, Cap.= capability, NNIS = non-native invasive species, NLCD= National Land Cover Database.

Ecoregion Name Ecoregion Code	North Central U.S. Drift-less and Escarp-ment 222L	South-western Great Lakes Morainal 222K	Central Till Plains and Grand Prairies 251D	Central Dis-sected Till Plains 251C	Central Till Plains-Beech-Maple 222H	Central Till Plains-Oak Hickory 223G	Ozark High-lands 223A	Interior Low Plateau-Shawnee Hills 223D	White and Black River Alluvial Plains/ Coastal Plains-Loess 231H/234D	Total/ Average
Number of Species										
Total evaluated	53	66	79	80	62	89	82	87	95	77.0
Total present FIA plots	34	47	63	64	46	68	66	73	70	59.0
Total FIAsum	2124	620	553	2011	1319	2229	4381	5407	5069	2634.8
Species w/ FIAsum>10	24	17	20	32	28	39	50	51	59	35.6
Cap. 8.5 Very Good	4	0	0	3	0	1	7	15	14	4.9
Cap. 8.5 Good	11	13	10	16	14	23	22	19	17	16.1
Cap. 8.5 Fair	5	6	15	11	9	11	18	18	13	11.8
Cap. 8.5 Poor	5	10	19	12	10	15	9	4	12	10.7
Cap. 8.5 Very Poor	6	10	14	15	11	12	7	12	10	10.8
New Habitat	16	16	13	15	13	14	12	11	21	14.6
NNIS	2	5	2	2	1	3	2	3	3	2.6
FIA only	1	3	3	5	0	3	1	2	1	2.1
Migrate	12	11	6	10	8	5	5	3	10	7.8
Infill	21	15	32	34	14	40	38	46	17	28.6
Likely	3	2	2	0	2	2	0	1	1	1.4
unknown status	3	3	3	1	3	7	4	3	4	3.4
Land Cover 2016										
% NLCD Forest	30.0	10.6	6.1	23.2	23.3	22.5	35.7	61.0	35.6	27.6
%NLCD Agriculture	61.4	51.0	84.2	65.8	63.7	67.3	43.0	30.8	52.2	57.7
%NLCD Developed	5.5	35.0	8.5	6.8	10.9	7.7	13.5	5.1	5.9	11.0
FIA plot #/ ecoregion	15	71	119	258	8	298	78	155	32	1025
FIA plot #/buffers	79	109	213	352	56	422	147	276	171	1861

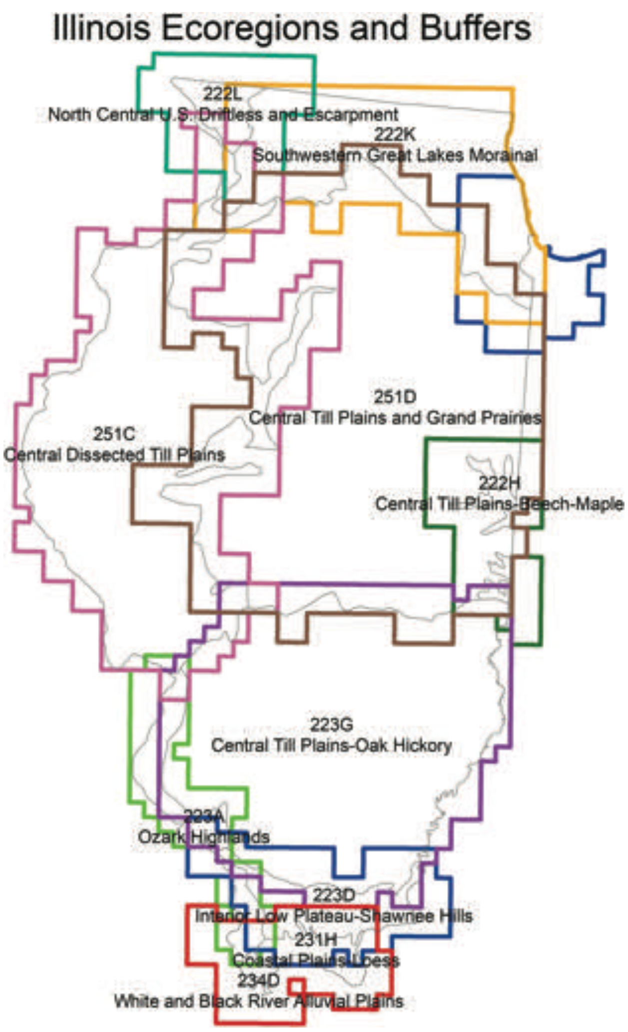

Figure 8. Ecoregions used in this analysis (see Figure 1) as buffered for sufficient FIA plots for statistical treatment. Buffered ecoregions overlap each other and even extend beyond the Illinois boundary to achieve a minimum of 8,000 km^2 area.

or the highly urbanized landscape of northeastern Illinois (222K), which is >35% developed but still with a large amount of non-developed forest. Urban areas typically were not well sampled via the normal FIA protocols, thus relatively less dense sample plots are available for this ecoregion. Nevertheless, there is a general north-to-south increase in tree species number, following general latitudinal trends globally. For example, the number of species recorded by forest inventory plots ranged from 34 in the northwest corner of the state to 73 in the Shawnee Hills in the south. Of these, the total number of common species, with *FIAsum* > 10, ranged from 17 in the Southwestern Great Lakes Morainal to 59 species in the southernmost ecoregion. The species-rich White and Black River Alluvial Plains and Coastal Plains-Loess ecoregions in southernmost Illinois include unique habitats, such as forested swamps, interspersed among the upland forests more typical of the Shawnee Hills region. Importance of individual species also varies widely along a north-to-south latitudinal gradient. For example, *Liriodendron tulipifera* and *Sassafras albidum* are almost exclusively in the southern ecoregions while *Quercus macrocarpa* and *Populus tremuloides* are primarily in the north (*Q. macrocarpa* is found statewide but has greater *FIAsum* values in northern regions). We recognize there are also east-west gradients for eastern North America tree species, but the shape of Illinois allows for a more robust analysis of north-south gradients.

Summary tables of tree species' projected responses to climate change are available for various watersheds, urban areas, and 1×1 degree grid locations within Illinois or anywhere in the eastern U.S. (USDA 2019b; Iverson *et al.* 2019a).

Capability

Across all ecoregions, there are roughly equivalent numbers of species with good or very good capability (mean across regions = 21.0) compared with species with poor or very poor capability (21.5), and another nearly 12 species with fair capability (Table 2). Because capability is based on current abundance, projected change in suitable habitat, and adaptability of the species, any of these traits can influence the capability of the species, and the capability varies widely among the nine ecoregions (Appendix). The southern ecoregions, once again, are expected to fare well, with 31-34 species with good or fair capability to cope or persist under climate change at the RCP8.5 level (Table 2). Based on an assessment of statewide capability (though we emphasize the spatial variability among ecoregions), the top-ranked species that would be expected to cope or persist well in the changing climate are *Liquidambar styraciflua*, *Quercus stellata*, and *Ulmus alata*, followed closely by *Quercus pagoda*, *Carya cordiformis*, *Celtis occidentalis*, *Juniperus virginiana*, and *Gleditsia triacanthos* (Table 3). Of the 20 species ranked with *MeanCap* 4.0 (good) or greater, seven are oaks (*Quercus* spp.). Median capability for all species currently in Illinois is 2.8. Some species currently ranked with the highest *Total FIAsum* within the state (>700) had ecoregion-specific capability rankings that were often poor to fair in some ecoregions, including *Liriodendron tulipifera*, *Quercus velutina*, *Carya glabra*, *Prunus serotina*, and *Juglans nigra* (Appendix). The capability of some species to persist in a changing climate varies by ecoregion. For example, *Q. alba*, the State tree, ranking with *MeanCap* just above fair (3.1), has wide variation among ecoregions from good and very good (in the southernmost two ecoregions and

Table 3: Tree species in Illinois scoring with good to very good capability to cope with ongoing and expected climate change under high (RCP 8.5) emissions. *Total FIAsum* is the sum of species importance across all ecoregions and is a measure of statewide importance based on FIA sample data, *MeanCap* = average capability among ecoregions where a species is present, * = non-native species.

Scientific_Name	Common_Name	*Total FIAsum*	*MeanCap*
Liquidambar styraciflua	sweetgum	590.6	4.5
Quercus stellata	post oak	493.5	4.5
Ulmus alata	winged elm	400.9	4.5
Quercus pagoda	cherrybark oak	150.7	4.4
Carya cordiformis	bitternut hickory	375.4	4.3
Celtis occidentalis	hackberry	758.6	4.3
Juniperus virginiana	eastern redcedar	562.3	4.3
Gleditsia triacanthos	honey locust	380.3	4.1
Acer saccharinum	silver maple	834.5	4.0
Carya texana	black hickory	97.7	4.0
Celtis laevigata	sugarberry	91.9	4.0
Diospyros virginiana	common persimmon	119.1	4.0
*Maclura pomifera**	Osage-orange*	158.4	4.0
Nyssa sylvatica	blackgum	179.8	4.0
*Pinus taeda**	loblolly pine*	77.8	4.0
Quercus falcata	southern red oak	113.1	4.0
Quercus marilandica	blackjack oak	27.2	4.0
Quercus phellos	willow oak	0.3	4.0
Quercus shumardii	Shumard oak	23.1	4.0
Quercus texana	Nuttall oak	0.5	4.0

the far northwest) to poor (the northeastern quarter of Illinois) (Appendix), suggesting no correlation to a latitudinal response but rather a correlation to current abundance of the species. In contrast, *Ulmus americana* has better capability in southern Illinois compared to northern ecoregions (although, this assumes resistance to Dutch elm disease), while *Acer saccharum* has much greater capability ratings in northern regions.

Species currently present in the state with capability ranking poor to very poor (Table 4) include species that are uncommon to start with, meaning few individuals are likely to find refuge in suitable habitat with favorable climate conditions in the coming decades. However, some relatively common species (*Total FIAsum* > 100) also have low (poor to very poor) future capabilities, including *Carya glabra*, *Salix nigra*, *Tilia americana*, *Quercus imbricaria*, *Q. palustris*, and *Q. muhlenbergii*. Familiar species with the lowest *MeanCap* include *Populus tremuloides, P. grandidentata*, *Pinus strobus*, *Betula nigra*, *Asimina triloba*, and *Aesculus glabra* (Table 4).

New Habitat and Migrate Species

The DISTRIB-II model identifies a range of 11 to 21 ‘New Habitat’ species, depending on ecoregion, with habitat under RCP8.5 appearing in Illinois by 2100 (Table 2). Of these, the ‘Migrate’ variable forms a subset of species that, according to the SHIFT model, provide a better indication of potential natural migration from zones farther south as well as provide a narrowed list of species to be considered as candidates for assisted migration. On average across all ecoregions, a little over half (7.8 out of 14.6) of the species with habitat potentially appearing are ‘Migrate Species’ (Table 2). Statewide, 19 are considered ‘New Habitat’ species, and of these, 10 are considered ‘Migrate’ species (Table 5), taxa that have the best chance of appearing naturally. Included among ‘Migrate’ species are *Carya aquatica* and *Planera aquatica*, two species that occur in swamps and wet forests in southernmost regions of Illinois but are rare and not captured in FIA samples. ‘New Habitat’ species also could be considered for assisted migration, should managers wish to pro-actively establish species; however, the SHIFT model does not project natural migration into at least one of the Illinois ecoregions within 100 years as it does for the ‘Migrate’ species.

DISCUSSION

Tree Species and Forest Communities

Understanding past changes to vegetation communities provide a historical context for evaluating on-

Table 4: Tree species in Illinois scoring with poor or very poor capability to cope with ongoing and expected climate change under high (RCP 8.5) emissions. *Total FIAsum* is the sum of species importance across all ecoregions and is a measure of statewide importance based on FIA sample data, *MeanCap* = average capability among ecoregions where a species is present, * = non-native species.

Scientific_Name	Common_Name	*Total FIAsum*	*MeanCap*
Acer nigrum	black maple	46.0	2.0
Pinus banksiana	jack pine	3.1	2.0
*Pinus virginiana**	Virginia pine*	17.6	2.0
Quercus ellipsoidalis	northern pin oak	11.0	2.0
Quercus imbricaria	shingle oak	351.4	2.0
Quercus michauxii	swamp chestnut oak	12.2	2.0
Taxodium distichum	bald cypress	63.7	2.0
Carya glabra	pignut hickory	982.9	1.9
Quercus muehlenbergii	chinkapin oak	112.2	1.9
Betula nigra	river birch	65.2	1.7
Salix nigra	black willow	537.8	1.7
Quercus bicolor	swamp white oak	43.1	1.6
Quercus coccinea	scarlet oak	53.4	1.5
Quercus palustris	pin oak	237.8	1.4
Amelanchier spp.	serviceberry	14.4	1.1
Tilia americana	American basswood	291.3	1.1
Aesculus glabra	Ohio buckeye	45.6	1.0
Asimina triloba	pawpaw	38.3	1.0
Betula papyrifera	paper birch	3.3	1.0
Fraxinus nigra	black ash	10.7	1.0
Fraxinus quadrangulata	blue ash	0.7	1.0
Magnolia acuminata	cucumbertree	12.4	1.0
Nyssa aquatica	water tupelo	26.2	1.0
*Picea glauca**	white spruce*	0.5	1.0
Pinus resinosa	red pine	17.9	1.0
Pinus strobus	eastern white pine	95.7	1.0
Populus balsamifera	balsam poplar	0.5	1.0
Populus grandidentata	bigtooth aspen	15.6	1.0
Populus tremuloides	quaking aspen	35.4	1.0

going changes (Petit *et al.* 2008). In our review, we note vegetation types such as tundra and spruce forest formerly found within what would become the state boundaries that today are located in Canada. Mean increase in global temperatures during the next 100 years are estimated to range from 2-5º C (O'Neill *et al.* 2016). Although the projected changes in Illinois forest composition during the next 100 years don't at first compare to the magnitude of the changes since the late Pleistocene, the influences of the ongoing changing climate do pose major challenges for conservation efforts to sustain *in situ* species assemblages. At currently projected levels of atmospheric emissions, the rate of climate change is expected to exceed the capacity for many species to adapt or migrate, particularly in a highly fragmented landscape (Handler *et al.* 2018). We expect species ranked with poor capability to gradually decline over the next 100 years, both by mortality of mature individuals and declining recruitment.

Increasing species richness from north to south for a wide variety of species groups is one of the most fundamental observed geographically based biotic trends (Fischer 1960; Schemske *et al.* 2009) and the pattern holds true for tree species along the nearly 650-km latitudinal gradient in Illinois (Taft *et al.* 2009; USDA 2019a). This pattern could magnify with the changing climate if northern species (e.g., *Populus tremuloides, Betula papyrifera*), occurring in Illinois near their southern range extent in the Midwest, decline disproportionately to southern species. Warming over the past century (Wuebbles *et al.* 2021) may have already contributed to declining populations for many northern species and many tree species demonstrate marked differences in projected future capabilities corresponding to the north-to-south latitudinal gradient.

Table 5: New Habitat species, species with habitat conditions potentially entering the state during the next 100 years under RCP8.5, and Migrate species, species with potential to naturally migrate into the state in that time frame. Migrate species differentiated by: RCP8.5 - potential to migrate only under the higher emissions scenario; Either - potential to migrate under low or higher emission scenario; Native – species rare in Illinois and missed by FIA plots; Poss. native - species possibly in Illinois but missed by FIA plots.

Scientific_Name	Common_Name	New Habitat	Migrate
Acer barbatum	Florida maple	x	Either
Acer pensylvanicum	striped maple	x	
Carya aquatica	water hickory	x	Native
Ilex opaca	American holly	x	RCP8.5
Juniperus ashei	ashe juniper	x	
Magnolia grandiflora	southern magnolia	x	
Magnolia virginiana	sweetbay	x	RCP8.5
Nyssa biflora	swamp tupelo	x	Poss. native
Oxydendrum arboreum	sourwood	x	
Persea borbonia	redbay	x	
Pinus elliottii	slash pine	x	
Pinus palustris	longleaf pine	x	
Planera aquatica	water elm	x	Native
Prunus pensylvanica	pin cherry	x	
Quercus laurifolia	laurel oak	x	Either
Quercus nigra	water oak	x	Either
Quercus virginiana	live oak	x	
Sideroxylon lanuginosum	cittamwood/gum bumelia	x	Either
Ulmus crassifolia	cedar elm	x	RCP8.5

To discuss changes in species composition that we can expect in the major forest and woodland types in Illinois, we use the IDNR (2010) natural community classification, a modification of White and Madany (1978), as a framework. There are major differences in capacity to cope with the expected new climate, at least regionally, among some of the more dominant and characteristic tree species in natural communities across the moisture gradient, from dry woodland to wet floodplain forest and swamp.

Dry to Dry-Mesic Woodland and Related Communities

Tree species response models to climate change suggest that many dominant species in oak-hickory stands, the predominant cover type in Illinois, will have fair-to-good capabilities (e.g., *Quercus stellata*, *Q. marilandica*, *Q. falcata*, *Q. rubra*, *Carya texana*, *C. alba*, and *Ulmus alata*). Notable exceptions include *C. glabra* (including *C. ovalis* in FIA nomenclature) and *Q. muhlenbergii*, two species scoring with poor capabilities. *Carya ovata*, a characteristic co-dominant species of many upland stands, has only poor-to-fair capability. *Quercus alba* and *Q. velutina*, two of the more dominant species of upland wooded communities statewide, score with fair to just below fair capability, respectively. *Quercus macrocarpa*, a species found in a wide range of wooded community types, including savanna, has projected capability ranging from very poor in the far south to fair, only scoring good in northwestern Illinois. Trends among these latter three seminal species will depend on factors related to regeneration and recruitment dynamics. For example, some shade-tolerant and moisture-loving species (e.g., *Acer saccharum*), symptomatic of mesophication when established in understories of oak-dominated stands (Nowacki and Abrams 2008) and with the capacity to out-compete oaks particularly without burning, also are projected to have fair-to-good capabilities. Thus, outcomes for *Q. alba*, *Q. velutina*, and *Q. macrocarpa*, particularly, will hinge in part on how woodlands are managed. In addition to prescribed fire, silvicultural practices can be adapted that are designed to promote key species in the face of climate change (Nagel *et al.* 2017).

Quercus stellata, a characteristic species in upland woodland communities throughout the southern half of the state, is particularly dominant in barrens (Heikens and Robertson 1994) and southern flatwoods (Taft *et al.* 1995) and ranks among the three species with the highest capability to endure climate change. One of the others, *Ulmus alata*, a common associate of *Q. stellata*, can form thickets in dry and xeric woodlands and barrens in the southern quarter of Illinois. Both species are projected to find new habitat, based on wide tolerances of climatic and edaphic conditions, in ecoregions north of current ranges and when abundant, both species can contribute to competition and shading of ground-layer species, resulting in species attrition (Taft 2009). Tree density of both *Q. stellata* and *U. alata* can be controlled with burning, but the practice of using prescribed fire needs to be maintained. Fire-return intervals greater than a few years can lead to further thicketization (Taft 2020).

Mesic Upland Forests

Characteristic species of mesic upland stands include a particularly wide range of projected responses to climate change. For example, *Acer saccharum*, *Quercus rubra*, and *Carya cordiformis* have fair to very good capabilities; *Fagus grandiflora* and *Carpinus caroliniana* have capabilities ranging from very poor (northern regions) to good (southern regions). In sharp contrast to *A. saccharum*, *Q. rubra*, and *C. cordiformis*, the characteristic species *Tilia americana*, *Aesculus glabra*, and *Asimina triloba* have very poor capabilities, among the lowest among species examined.

Sand Communities

Sand forest, woodland, and savanna are characterized statewide by dominance of *Quercus velutina* (Marcum *et al.* 2013). However, several other oaks with variable projected capacities to endure the expected climate changes, also can be found in wooded sand communities. These include, from across the dry-to-wet moisture gradient, *Quercus marilandica*, *Q. alba*, *Q. rubra*, *Q. ellipsoidalis*, and *Q. palustris*. *Quercus velutina* scored at the *MeanCap* median, between poor and fair capacity; the other upland species fare better with *Q. marilandica* ranked with good capacity. However, *Q. ellipsoidalis* and *Q. palustris*, observed in sand flatwoods in northeastern Illinois (Marcum *et al.* 2022), rank among the species with poorest capacity to endure expected climate changes within the state boundaries.

Floodplain Forests

The wide range of characteristic species of mesic to wet floodplain forest habitats include, due to expected highly fluctuating moisture regimes, about as many fair-to-very good capabilities as there are those scoring with very poor to poor capabilities. As such, we can expect notable shifts in species' suitable habitats, with trends towards more *Gleditsia triacanthos*, *Acer saccharinum*, *Liquidambar styraciflua*, *Celtis occidentalis*, *C. laevigata*, and *Ulmus americana*. On the other hand, less *Quercus palustris, Q. bicolor, Tilia americana*, *Asimina triloba*, *Carya laciniosa*, *Betula nigra*, and *Salix nigra* may be expected. *Liquidambar styraciflua* ranks as one of the species with the highest capability with a projection for new habitat in currently unoccupied northern ecoregions. *Fraxinus pennsylvanica* is projected to have fair capability but likely will continue to be impacted negatively by emerald ash borer.

Forested Swamp

Due to their relative scarcity, *Nyssa aquatica* and *Taxodium distichum* are projected to have very poor to poor capabilities. Some bottomland oaks associated with swamps, such as *Quercus michauxii*, *Q. lyrata*, and *Q. shumardii*, range in capability from poor, to fair, and good, respectively.

Response of Other Forest Species

Populations of understory and ground-layer plants in forests are greatly influenced by light and moisture availability and likely also will be affected by climate change. Although risk and likelihood of wildland fire in the western United States is increasing due to climate change, it is unclear whether we can expect more unplanned wildfires in Illinois in coming years. Of midwestern states, Illinois has the fewest wildfires and least annual average area burned by wildfires (Midwestern Regional Climate Center 2021), most likely due to the highly fragmented nature of the landscape and the overall low percentage of forest. Species adapted to abundant sunlight may benefit if fires increase in frequency and create a more open forest structure, but they would likely decline in the absence of fire and increased shading by the overstory. If sunlight is not limiting, warm-season plants that thrive during the summer may have advantage over cool-season species, since climate change is projected to increase average temperatures; these include the grasses of savanna and open woodland habitats, which also occur in prairies. However, warm-season grasses with the C_4 photosynthetic pathway, adapted to fix carbon at lower CO_2 levels than C_3 plants, may not be advantaged relative to C_3 plants under elevated CO_2 levels (Wang and Greenberg 2007); consequently, the outcome is complex and unclear.

Many rare plant species in Illinois are found in the northern ecoregions and occur in Illinois at the southernmost extent of their midwestern ranges (e.g., *Taxus canadensis*, *Betula alleghaniensis*, *Cornus canadensis*, various orchids, ferns and fern allies). These species typically have persisted in specialized habitats such as forest seeps, cooler north-facing forested slopes, peatlands, and canyon walls. Because many of these species are likely boreal relicts from a former time, they are likely to be at risk from a warmer climate and the likelihood of increasingly severe summer droughts (Wuebbles *et al.* 2021). Certain invasive, non-native species such as *Lonicera maackii*, *Celastrus orbiculatus*, and *Microstegium vimineum* could also become more problematic in remaining forests or future restorations because they are likely to benefit from longer growing seasons and milder winters.

Wildlife species are generally more mobile than plants and may be able to migrate in response to climate change. However, the ability of wildlife to migrate may be limited by the highly fragmented landscape in Illinois and a lack of adequate natural corridors to facilitate movement. There is also a risk of disrupted species interactions, particularly between pollinator and host-plant species.

Restoration and Preserve Design

On a per-area basis, forests have been reported to rank highest among all ecosystems in the Midwest for potential for carbon sequestration and help mitigate the effects of increasing CO_2 (Fargione *et al.* 2018). With forest cover currently only at 32% of the baseline at the time of Euro-American settlement, there are opportunities to plan reforestations to consolidate forest and woodland fragments. Reducing isolation of habitat fragments will allow for greater migration corridors for a wide range of plant and wildlife species. Forming large, consolidated conservation areas enhances conserving biodiversity by including greater levels of habitat heterogeneity within the established boundaries.

Assisted migration, or the introduction of a species outside its native range (McLachland *et al.* 2007), has been suggested for selected species of conservation concern (Barlow 2011) as a hedge against extinction resulting from climate change (Schwartz *et al.* 2012), but also to enhance survival of tree species not necessarily at risk of extinction (Pedlar *et al.* 2012; Iverson and McKenzie 2013; Williams and Dumroesse 2013; Handler *et al.* 2018). Experimental plantings under controlled conditions could be considered to test performance of tree species identified as candidates for migration (Table 5) to more northern locations (Iverson *et al.* 2019b). This effort is currently underway with multiple Adaptive Silviculture for Climate Change sites across the United States (Nagel *et al.* 2017; ASCC 2021) and other demonstrations assisted by the Northern Institute of Applied Climate Science (NIACS 2021). The topic is complex with many unknowns (Park and Talbot 2018) but unless CO_2 levels can be reduced well below RCP 8.5 projections, assisted migration may become increasingly necessary to allow species to keep pace with alterations and northward movement of optimal climatic conditions for many characteristic species of Illinois wooded habitats.

CONCLUSIONS

Efforts to maintain Illinois forests in the face of climate change are important because these ecosystems provide critical habitat to native flora and fauna, as well as numerous other benefits like clean air and water, and recreational opportunities. Conserving and restoring forests in the state also has the potential to contribute to both sequestering carbon emissions and building more resilience to climate change. Support for the formation of large forest conservation areas and corridors through both private and public consortia will be needed to maintain and enhance forest health and biodiversity in the state.

In this modeling study, we have attempted to provide insights into the potential modifications in forest communities in the coming decades under the changing climate. We first must emphasize that 'All models are wrong, some are useful' (Box and Draper 1987); our intention is to provide useful summaries of current tree species status and potential changes under climate change for nine Illinois ecoregions. As such, they are for adding to the toolbox managers may use in decisions related to regional forest management. For local managers, perhaps they can be of use to narrow the decision space in light of myriad options; but certainly, local knowledge of habitats and species requirements are necessary for any on-ground actions. We encourage testing and modification of these modeling results in hopes that with time, the best adaptation practices can be achieved for the forests of Illinois.

Effectively addressing the impacts of climate change on forests in Illinois will also require coordinated management, restoration, and protection plans informed by habitat monitoring. Many specific management practices can be included within these plans to foster habitat integrity and the maintenance of characteristic forest types in Illinois. Managers also need to be amenable to possible adjustments to management practices considering the cascading impacts from a changing climate. For example, the use of prescribed fire is an important tool to facilitate and promote the maintenance of oak-dominated habitats and the associated highly diverse ground-layer species. Yet, prescribed fire may be more difficult to achieve over large areas in the future because of increasing fragmentation of Illinois forests (Crocker *et al.* 2015) and the increasing variability of climate, possibly narrowing windows for implementation. Innovative harvesting techniques may also be needed to achieve goals of maintaining oak-hickory predominance in upland stands (e.g., Iverson *et al.* 2017). The silvicultural techniques continually need to be evaluated considering ongoing climate change (e.g., Iverson *et al.* 2019c) and increasing pressure from invasive species (Dukes *et al.* 2009). For example, *Ailanthus altissima* spread can be facilitated by certain silvicultural actions (Rebbeck *et al.* 2017) and we expect this to be true for other invasive non-native species such as *Morus alba*. Vigilant invasive species control is required to maintain ecosystem integrity in most forest stands. In certain cases, especially where habitat fragmentation is particularly pronounced, assisted migration may be needed to establish species whose suitable habitat is shifting into more northern areas.

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Appendix: Tree species from Forest Inventory and Analysis sample data (USDA 2019) shown in descending rank order of species importance (*Tle FIAsum*). Species importance values (*FIAsum*) based on abundance and areal coverage and capability (*Cap*) to cope or persist under climate change by 2100 according to higher emission models. Capability ratings are scored as VG = very good, G = good, F = fair, P = poor, VP = very poor; NH = New Habitat species with habitat by 2100; FIA = only current estimate made as insufficient data exist for modeling into the future; NNIS = non-native invasive species; Unk = unknown status. The NH species coded as: NH* = Migrate pecies with some likelihood of migration into the ecoregion within 100 years under either climate scenario, NH+ = species with potential to migrate under only the higher scenario, and NH# = species likely present but not detected in inventory plots. Ecoregion map# refer to Figures 1 and 8.

	Ecoregion	North Central U.S. Driftless and Escarpment		Southwestern Great Lakes Morainal		Central Till Plains and Grand Prairies		Central Dissected Till Plains		Central Till Plains-Beech-Maple		Central Till Plains-Oak Hickory		Ozark Highlands		Interior Low Plateau-Shawnee Hills		White and Black River Alluvial Plains/Coastal Plains-Loess			
	Ecoregion map#	**222L**		**222K**		**251D**		**251C**		**222H**		**223G**		**223A**		**223D**		**231H & 234D**			
Scientific_Name	**Common_Name**	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***FIAsum***	***Cap***	***Ttl FIAsum***	***MeanCap***
Quercus alba	white oak	93.6	VG	44.3	P	33.3	P	139.3	F	77.1	F	127.0	F	296.5	F	462.6	F	372.5	G	1636.2	3.1
Acer saccharum	sugar maple	44.8	G	7.1	F	25.5	F	75.9	VG	127.0	F	69.6	VG	229.5	G	399.7	F	252.1	F	1231.1	3.7
Ulmus americana	American elm	254.2	F	31.1	G	33.2	F	205.5	F	31.9	G	122.1	G	190.1	G	167.9	VG	124.1	VG	1160.2	3.9
Liriodendron tulipifera	yellow-poplar	0.0	NH+	0.0	NH	8.6	P	0.0	NH*	123.1	F	40.7	P	211.5	F	358.9	F	293.4	F	1036.1	2.7
Quercus velutina	black oak	47.6	G	19.6	F	18.5	P	114.0	P	32.2	P	70.8	F	215.2	F	265.6	F	217.3	F	1000.8	2.8
Carya glabra	pignut hickory	0.0	NH+	0.0	NH#	1.9	P	23.3	P	18.2	VP	82.6	P	195.1	P	366.9	P	295.0	P	982.9	1.9
Acer negundo	boxelder	175.8	F	87.5	F	12.3	F	27.7	G	17.6	G	90.7	F	203.9	G	119.6	VG	123.1	VG	858.3	3.8
Acer saccharinum	silver maple	23.7	G	9.4	G	29.6	G	131.4	G	45.7	G	98.4	G	120.0	VG	261.8	F	114.5	G	834.5	4.0
Fraxinus pennsylvanica	green ash	21.9	G	24.1	F	16.8	G	41.5	G	13.9	G	101.6	G	153.1	G	220.5	G	189.8	G	783.1	3.9
Prunus serotina	black cherry	153.0	P	87.3	VP	51.8	VP	85.9	P	116.4	VP	74.0	P	50.4	F	67.5	G	88.1	F	774.4	2.1
Celtis occidentalis	hackberry	94.5	VG	10.6	G	26.4	G	79.9	VG	6.7	G	159.8	F	157.0	VG	106.6	VG	117.2	G	758.6	4.3
Juglans nigra	black walnut	240.8	P	35.9	P	35.0	P	75.9	G	54.8	G	66.3	F	70.6	G	64.3	F	60.0	P	703.6	2.9
Quercus rubra	northern red oak	68.1	VG	12.8	G	14.6	P	79.7	F	95.8	F	35.6	P	143.6	F	113.3	G	53.7	VG	617.2	3.4
Liquidambar styraciflua	sweetgum	-	-	0.0	NH	0.1	G	0.0	NH*	0.6	G	16.9	G	114.0	VG	213.8	VG	245.2	VG	590.6	4.5
Sassafras albidum	sassafras	0.0	NH+	0.0	NH#	3.1	P	29.7	P	55.4	P	73.3	P	144.9	P	149.7	F	119.3	F	575.5	2.3
Fraxinus americana	white ash	32.0	F	9.3	F	11.5	P	59.7	F	40.0	P	63.5	F	95.7	F	146.5	F	114.3	F	572.5	2.8
Juniperus virginiana	eastern redcedar	174.0	G	0.8	G	4.0	G	28.4	G	9.0	G	18.9	G	122.6	VG	128.0	VG	76.6	VG	562.3	4.3
Carya ovata	shagbark hickory	72.9	F	20.9	VP	10.1	F	95.2	P	27.5	P	83.9	P	74.3	F	94.1	F	82.9	F	561.7	2.4
Salix nigra	black willow	0.0	NH#	1.2	P	11.1	VP	44.3	VP	0.0	NH#	37.6	VP	164.7	P	48.8	F	230.1	P	537.8	1.7
Quercus stellata	post oak	0.0	NH*	0.0	NH*	1.2	G	11.3	G	0.0	NH*	49.6	G	142.4	VG	162.9	VG	126.2	VG	493.5	4.5
Ulmus rubra	slippery elm	79.0	F	7.0	G	11.1	F	47.1	F	48.6	P	26.4	G	80.2	VG	72.5	VG	60.3	VG	432.1	3.8
Ulmus alata	winged elm	-	-	0.0	NH+	0.0	NH*	0.0	NH*	0.0	NH*	22.7	G	32.3	G	157.0	VG	188.9	VG	400.9	4.5
Gleditsia triacanthos	honeylocust	4.9	G	7.4	G	30.8	F	74.2	VG	53.4	G	71.9	G	36.0	G	52.3	VG	49.4	G	380.3	4.1
Platanus occidentalis	sycamore	0.0	NH*	0.4	G	4.5	P	31.4	P	34.0	F	45.5	F	107.8	G	63.7	VG	88.2	VG	375.5	3.5
Carya cordiformis	bitternut hickory	63.7	VG	4.3	G	9.9	G	52.5	G	29.7	F	40.4	G	54.5	VG	52.9	VG	67.6	VG	375.4	4.3
Pinus echinata	shortleaf pine	-	-	-	-	-	-	-	-	-	-	11.9	P	12.1	F	187.3	G	140.7	G	352.0	3.3
Quercus imbricaria	shingle oak	0.0	NH*	0.0	NH*	12.1	P	86.4	P	41.3	VP	91.2	P	63.4	P	33.9	F	23.2	P	351.4	2.0
Tilia americana	American basswood	190.5	P	19.9	VP	8.0	VP	48.4	VP	15.3	VP	2.7	VP	3.2	VP	0.6	VP	2.8	VP	291.3	1.1
Populus deltoides	eastern cottonwood	3.5	G	14.5	G	16.8	F	38.9	F	7.8	G	59.9	P	42.7	F	45.4	VP	60.7	P	290.1	2.9
Acer rubrum	red maple	0.0	NH*	3.1	P	1.8	F	0.1	G	11.2	F	66.1	G	33.3	G	74.1	VG	82.7	VG	272.2	3.8
Robinia pseudoacacia#	black locust#	4.2	G	14.4	P	8.3	P	31.5	F	1.7	G	28.4	P	108.6	F	22.9	G	49.1	F	269.0	3.0
Quercus palustris	pin oak	-	-	0.1	F	2.3	VP	10.1	VP	4.7	VP	43.4	VP	58.1	P	54.5	VP	64.6	VP	237.8	1.4
Carya alba	mockernut hickory	0.0	NH*	0.0	NH+	5.0	F	17.6	G	24.2	P	32.1	G	42.1	G	67.8	VG	43.8	G	232.6	3.7
Quercus macrocarpa	bur oak	124.8	G	43.6	P	21.4	F	10.0	F	13.8	F	12.5	P	1.0	VP	1.1	VP	-	-	228.2	2.4
Ostrya virginiana	eastern hophornbeam; ir	19.6	G	2.3	G	5.2	F	33.9	P	28.3	P	10.3	F	41.9	G	36.1	G	43.5	G	221.0	3.3
Morus rubra	red mulberry	27.0	P	1.5	G	8.9	F	34.8	F	8.8	P	17.8	VP	66.2	P	13.7	G	39.7	P	218.3	2.6
Nyssa sylvatica	blackgum	-	-	-	-	0.1	F	0.0	NH+	0.9	F	6.7	G	26.1	G	70.5	VG	75.6	VG	179.8	4.0
*Maclura pomifera^*	Osage-orange^	0.0	NH*	1.5	G	23.1	G	46.4	G	38.9	G	36.9	G	11.2	G	0.5	G	0.0	NH+	158.4	4.0
Quercus pagoda	cherrybark oak	-	-	-	-	0.0	NH+	1.0	G	0.0	NH	3.5	G	10.4	G	57.2	VG	78.5	VG	150.7	4.4
Fagus grandifolia	American beech	-	-	-	-	0.2	VP	0.0	NH*	4.1	VP	2.3	F	64.0	F	41.3	G	33.7	G	145.6	2.7
Diospyros virginiana	common persimmon	0.0	NH+	0.0	NH+	0.0	NH#	3.1	G	7.2	G	20.1	G	21.0	G	28.7	G	39.0	G	119.1	4.0
Quercus falcata	southern red oak	-	-	-	-	0.0	NH+	3.3	F	0.0	NH+	3.8	G	9.5	G	16.1	G	80.4	VG	113.1	4.0
Quercus muehlenbergii	chinkapin oak	0.0	NH#	0.0	NH*	2.6	P	5.2	P	18.3	VP	6.3	VP	25.5	F	24.7	F	29.8	VP	112.2	1.9
Cornus florida	flowering dogwood	0.0	NH#	0.0	Unk	0.2	VP	5.0	P	3.6	VP	6.2	P	27.6	F	39.5	F	27.5	F	109.6	2.1
Carya texana	black hickory	0.0	NH+	0.0	NH+	0.3	G	1.3	G	0.0	NH+	3.7	G	39.8	G	28.6	G	23.9	G	97.7	4.0
Pinus strobus#	eastern white pine#	10.4	VP	31.9	VP	6.7	VP	7.3	VP	-	-	0.8	VP	-	-	19.1	VP	19.7	VP	95.7	1.0
Celtis laevigata	sugarberry	0.0	NH	0.0	NH	0.0	G	7.6	G	0.0	NH+	1.3	G	52.5	G	5.2	G	25.3	G	91.9	4.0
Carya illinoinensis	pecan	-	-	0.0	NH*	0.1	F	2.5	F	0.0	NH#	5.0	F	39.5	F	19.7	F	21.1	F	87.9	3.0
Cercis canadensis	eastern redbud	0.0	NH*	0.0	NH*	0.6	F	10.6	P	0.7	G	17.1	P	27.5	F	14.7	G	12.3	F	83.4	3.0
*Pinus taeda^*	loblolly pine^	-	-	-	-	0.0	NH+	0.0	NH+	0.0	NH+	4.0	G	0.0	NH*	41.0	G	32.9	G	77.8	4.0
Betula nigra	river birch	-	-	-	-	0.5	VP	0.8	VP	1.8	VP	17.6	VP	0.6	F	19.6	F	24.3	P	65.2	1.7
Taxodium distichum	bald cypress	-	-	-	-	-	-	-	-	-	-	-	-	29.1	P	5.4	P	29.3	P	63.7	2.0
*Morus alba**	white mulberry*	25.7	NNIS	4.6	NNIS	4.4	NNIS	9.9	NNIS	-	-	3.6	NNIS	2.0	NNIS	2.1	NNIS	6.2	NNIS	58.6	
Carya laciniosa	shellbark hickory	-	-	-	-	0.3	P	0.8	VP	1.4	P	6.5	F	0.0	NH	8.3	F	38.1	P	55.4	2.2
Quercus coccinea	scarlet oak	-	-	-	-	-	-	-	-	-	-	0.5	P	18.3	P	17.9	VP	16.7	VP	53.4	1.5

Appendix: Continued.

	Ecoregion	North Central U.S. Driftless and Escarpment		Southwestern Great Lakes Morainal		Central Till Plains and Grand Prairies		Central Dissected Till Plains		Central Till Plains-Beech-Maple		Central Till Plains-Oak Hickory		Ozark Highlands		Interior Low Plateau-Shawnee Hills		White and Black River Alluvial Plains/Coastal Plains-Loess			
	Ecoregion map#	222L		222K		251D		251C		222H		223G		223A		223D		231H & 234D			
Scientific_Name	Common_Name	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	FIAsum	Cap	Ttl FIAsum	MeanCap
Acer nigrum	black maple	27.8	P	7.0	P	1.7	P	7.0	P	-	-	0.0	P	-	-	1.1	P	1.4	P	46.0	2.0
Aesculus glabra	Ohio buckeye	-	-	-	-	1.8	VP	6.5	VP	7.7	VP	2.0	VP	27.4	VP	0.3	VP	0.0	Unk	45.6	1.0
Quercus bicolor	swamp white oak	1.7	G	1.8	P	1.0	P	9.3	VP	-	-	2.6	VP	9.1	VP	4.9	VP	12.7	VP	43.1	1.6
Fraxinus profunda	pumpkin ash	-	-	-	-	-	-	-	-	-	-	-	-	3.2	FIA	17.1	FIA	19.8	FIA	40.1	
Asimina triloba	pawpaw	0.0	Unk	-	-	0.4	VP	1.5	VP	2.6	VP	1.2	VP	8.3	VP	11.5	VP	12.7	VP	38.3	1.0
Populus tremuloides	quaking aspen	28.5	VP	6.8	VP	0.1	VP	-	-	-	-	-	-	-	-	-	-	0.0	Unk	35.4	1.0
Quercus prinus	chestnut oak	-	-	-	-	-	-	-	-	-	-	0.0	NH	10.4	F	8.1	F	10.2	F	28.7	3.0
Quercus marilandica	blackjack oak	-	-	0.0	NH*	0.0	NH+	0.2	G	0.0	NH+	2.5	G	10.9	G	9.9	G	3.7	G	27.2	4.0
Nyssa aquatica	water tupelo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.4	VP	17.8	VP	26.2	1.0
Carpinus caroliniana	American hornbeam	-	-	-	-	0.3	P	1.0	VP	3.3	P	0.0	G	4.1	G	2.4	G	14.8	G	25.8	3.0
Catalpa speciosa	northern catalpa	0.6	FIA	0.2	FIA	1.7	FIA	2.2	FIA	-	-	3.9	FIA	-	-	15.0	FIA	-	-	23.6	
Quercus shumardii	Shumard oak	-	-	0.0	NH+	0.0	NH#	0.5	G	-	-	2.3	G	4.2	G	1.2	G	15.0	G	23.1	4.0
Pinus resinosa#	red pine#	4.5	VP	10.3	VP	1.2	VP	1.7	VP	-	-	0.2	VP	-	-	-	-	-	-	17.9	1.0
*Pinus virginiana^*	Virginia pine^	-	-	-	-	-	-	-	-	-	-	0.0	NH*	-	-	0.0	NH#	17.6	P	17.6	2.0
Populus grandidentata	bigtooth aspen	-	-	-	-	2.0	VP	0.7	VP	12.9	VP	0.0	Unk	-	-	0.0	Unk	-	-	15.6	1.0
Amelanchier spp.	serviceberry	0.0	Unk	0.4	VP	0.0	P	0.3	VP	0.0	Unk	0.3	VP	5.6	VP	2.3	VP	5.5	VP	14.4	1.1
*Pinus sylvestris**	Scotch pine*	-	-	12.3	NNIS	-	-	-	-	-	-	0.6	NNIS	-	-	0.2	NNIS	-	-	13.1	
Quercus lyrata	overcup oak	-	-	-	-	0.0	NH	0.0	NH+	-	-	0.0	NH#	1.8	F	2.2	F	8.8	F	12.8	3.0
Magnolia acuminata	cucumbertree	-	-	0.0	Unk	-	-	-	-	-	-	0.0	Unk	6.1	VP	2.6	VP	3.7	VP	12.4	1.0
*Ulmus pumila**	Siberian elm*	0.3	NNIS	0.3	NNIS	4.5	NNIS	6.6	NNIS	0.6	NNIS	-	-	-	-	-	-	-	-	12.3	
Quercus michauxii	swamp chestnut oak	-	-	-	-	-	-	-	-	-	-	0.0	NH#	1.5	P	1.5	P	9.2	P	12.2	2.0
Quercus ellipsoidalis	northern pin oak	1.6	VP	8.6	P	0.8	P	-	-	-	-	-	-	-	-	-	-	-	-	11.0	2.0
*Ailanthus altissima**	ailanthus*	-	-	-	-	-	-	-	-	-	-	1.0	NNIS	6.1	NNIS	3.2	NNIS	0.6	NNIS	10.8	
Fraxinus nigra	black ash	6.0	VP	3.1	VP	0.0	Unk	1.6	VP	0.0	Unk	-	-	0.0	Unk	-	-	-	-	10.7	1.0
*Picea abies**	Norway spruce*	-	-	8.7	NNIS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.7	
Betula papyrifera	paper birch	3.3	VP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.3	1.0
Pinus banksiana	jack pine	-	-	1.0	P	2.1	P	-	-	-	-	-	-	-	-	-	-	-	-	3.1	2.0
Prunus americana	wild plum	-	-	-	-	1.2	FIA	0.7	FIA	-	-	-	-	-	-	-	-	-	-	1.8	
Gymnocladus dioicus	Kentucky coffeetree	-	-	-	-	0.2	FIA	0.9	FIA	-	-	0.1	FIA	-	-	-	-	-	-	1.2	
Fraxinus quadrangulata	blue ash	-	-	-	-	0.3	VP	0.4	VP	-	-	0.0	Unk	-	-	-	-	-	-	0.7	1.0
*Paulownia tomentosa**	paulownia*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	NNIS	0.6	
Populus balsamifera#	balsam poplar#	-	-	0.5	VP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.0
*Picea glauca^*	white spruce^	-	-	0.5	VP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	1.0
Quercus texana	nuttall oak	-	-	-	-	-	-	-	-	-	-	-	-	0.3	G	0.2	G	0.0	NH	0.5	4.0
Juglans cinerea	butternut	-	-	-	-	-	-	0.4	FIA	-	-	0.0	FIA	-	-	-	-	-	-	0.4	
Quercus phellos	willow oak	-	-	-	-	-	-	0.0	NH*	-	-	0.0	NH*	0.0	NH*	0.0	NH*	0.3	G	0.3	4.0
Prunus virginiana	chokecherry	-	-	0.2	FIA	-	-	0.0	FIA	-	-	-	-	-	-	-	-	-	-	0.3	
*Acer platanoides**	Norway maple*	-	-	0.1	NNIS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	
Salix amygdaloides	peachleaf willow	-	-	0.1	FIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	
Acer barbatum	Florida maple	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH	0.0	NH	0.0	NH*		
*Acer pensylvanicum^*	striped maple^	-	-	-	-	-	-	0.0	NH	-	-	0.0	NH	0.0	NH	0.0	NH	0.0	NH		
Carya aquatica	water hickory	-	-	-	-	-	-	-	-	-	-	0.0	NH+	0.0	NH	-	-	0.0	NH#		
*Ilex opaca^*	American holly^	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH+		
*Juniperus ashei^*	ashe juniper^	-	-	-	-	-	-	0.0	NH	-	-	0.0	NH	0.0	NH	0.0	NH	0.0	NH		
*Magnolia grandiflora^*	southern magnolia^	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH		
*Magnolia virginiana^*	sweetbay^	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH+		
Nyssa biflora	swamp tupelo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH#		
*Oxydendrum arboreum^*	sourwood^	-	-	-	-	-	-	-	-	-	-	0.0	NH	0.0	NH	0.0	NH	0.0	NH		
*Persea borbonia^*	redbay^	-	-	-	-	-	-	-	-	-	-	0.0	Unk	-	-	-	-	0.0	NH		
*Pinus elliottii^*	slash pine^	-	-	-	-	0.0	NH	-	-	-	-	-	-	-	-	-	-	0.0	NH		
*Pinus palustris^*	longleaf pine^	-	-	-	-	0.0	NH	-	-	-	-	-	-	-	-	-	-	0.0	NH		
Planera aquatica	water elm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH#		
*Prunus pensylvanica^*	pin cherry^	0.0	Unk	-	-	0.0	Unk	0.0	NH	0.0	Unk	0.0	NH	0.0	Unk	0.0	NH	0.0	NH		
*Quercus laurifolia^*	laurel oak^	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	NH*		
*Quercus nigra^*	water oak^	-	-	-	-	0.0	NH	0.0	NH+	0.0	NH	0.0	NH*	0.0	NH*	0.0	NH*	0.0	NH*		
*Quercus virginiana^*	live oak^	-	-	-	-	-	-	0.0	NH	-	-	0.0	NH	0.0	NH	0.0	NH	0.0	NH		
Sideroxylon lanuginosum ^	cittamwood^	-	-	-	-	0.0	NH+	0.0	NH+	0.0	NH+	0.0	NH+	0.0	NH+	0.0	NH+	0.0	NH*		
*Ulmus crassifolia^*	cedar elm^	-	-	-	-	0.0	NH	0.0	NH	0.0	NH	0.0	NH	0.0	NH+	0.0	NH	0.0	NH+		

* species not native to North America

^ species native to North America, absent or adventive in Illinois (currently)

\# = native species but most occurrences outside natural range

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Unusual Form of the Annual *Collinsia verna* Nutt. (Blue-eyed Mary) Observed in Will County, Illinois

Michael Ostrowski[1,*] and Mark Kluge[2]

Abstract: Many typically blue or pink flowered plant species have been observed to have rare white forms. A white form of *Collinsia verna* Nutt., which typically has a bi-colored blue and white flower, was recently observed in Will County, Illinois. This paper documents this unusual form, discusses its rarity, and examines previous historical descriptions of the species.

Botanical Nomenclature: Wilhelm and Rericha (2017)

Introduction

Collinsia verna Nutt. is a distinctive annual species in the *Plantaginaceae*, easily recognized by its whorled inflorescence and bicolored corolla. Specifically, the upper lip is cleft into two large rounded lobes that are white, while the lower lip is cleft into three lobes (Figure 1). The two rounded outer lobes of the lower lip are light blue to blue-violet, while the middle lobe is folded into a keel and hidden from view (Illinois Wildflowers 2021).

Results

Observation of Unusual White-Flowered Form of *Collinsia verna*

On April 22, 2021 in Homer Glen (Will County, Illinois) five individuals of *Collinsia verna* were observed to have a corolla with the lower lobes having the same white coloration as the upper lobes (Figure 2). These five specimens were growing within a population of several hundred of the typical blue lower lip form. The upper lip of the aberrant form still exhibited the orange-pink speckling that is typical of *Collinsia verna*. The authors examined the population carefully for other examples or any intermediate forms; no intermediate form was present in the area.

This population was found growing in close proximity (approximately 15 meters) to a small, dry streambed that feeds into a nearby creek. The habitat is open mesic oak woodland with scattered maples, located within a dedicated Illinois Nature Preserve. The topography is rolling with ravines separating upland areas. The soil in the uplands is Ozaukee Silt Loam, a common morainal till component in northeast Illinois. Within the creek floodplain the soil is Pella Silty Clay Loam, typical of ground moraines and outwash plains (Hanson 2002). The observed plants were growing on a gentle slope in the transition from the upland to the floodplain, thus in one of these two soil types.

Associates of *Collinsia verna* at the observation site included *Asarum canadense*, *Dicentra cucullaria, Enemion biternatum, Erythronium albidum, Floerkea proserpinacoides, Galium aparine, Geranium maculatum, Mertensia virginica, Polygonatum biflorum, Trillium recurvatum, Viola pubescens,* and *Viola sororia*. *Mertensia virginica* is a dominant component of the floodplain flora. Since the white colored form of *Collinsia verna* was growing within a substantial population of the typical form, there was no distinction of associates observed between the forms.

White forms of customarily blue or pink flowered species have long been discussed in the literature (Moore 1941; Waser 1981). More recently, Wilhelm and Rericha (2017) have detailed several white-flowered forms of native species such as *Liatris aspera* f. *benkii*, *Monarda fistulosa* f. *albescens*, and *Phlox divaricata* f. *albiflora*, in the Chicago region. However, the authors could find no recent reference in the recent literature that acknowledged the existence of a white-flowered form of *Collinsia verna*. The historical literature is discussed below.

Historical Descriptions

Collinsia verna was first described by Nuttall as the type for the genus (Nuttall 1817). Nuttall first observed the species in 1810 but then lost the specimens. During

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Figure 1. Typical Form of *Collinsia verna* (photograph by Michael Ostrowski).

an 1816 trip he again found the species near Gallipolis, Ohio and collected its seed. This facilitated propagating the plant in order to provide a detailed description of the species.

Rafinesque (1824) proposed to rename the type as *Collinsia bicolor*, described several new forms, and also proposed two new species: *Collinsia alba* and *Collinsia purpurea*. None of these proposals of taxonomy gained any traction within the botanical community as the standard references maintained Nuttall's name (e.g., Gray 1856; Robinson and Fernald 1908). For the purposes of this paper, only Rafinesque's *Collinsia alba* is of interest. Rafinesque described the plant he found between Letart Falls and the mouth of the Kanawha River - today in Mason County, West Virginia. The pertinent features of this plant were large flowers, totally white, and small leaves.

Figure 2. Aberrant white form of *Collinsia verna* observed in Will County, IL (photograph by Mark Kluge).

The difficulty in assessing Rafinesque's descriptions is that few of his specimens survive. His personal herbarium of a reported 50,000 specimens was partly destroyed by rats. Nearly all of the remaining specimens were later discarded by Elias Durand who eventually purchased the collection (Merrill 1949). Pennell (1944) recounted that, of sixty new species described by Rafinesque in the Scrophulariaceae (in which *Collinsia* was formerly classified), only eight specimens survived. No specimen of Rafinesque's *Collinsia alba* is extant, so its precise relationship to the plants observed in Will County must include an element of uncertainty. Pennell (1935) stated that it "was evidently a depauperate, wholly white-flowered form of *C. verna* Nutt." The plants observed in Will County were not at all depauperate, and other than the white corollas, had the habit and proportions of the typical form.

Newsom's (1929) comprehensive treatment of the genus *Collinsia* relegated all of Rafinesque's designations to synonymy. Newsom further stated, "Variations in corolla color I am entirely disregarding, because if such were considered, innumerable varieties would have to be made." Pennell (1935) echoed the treatment of Rafinesqe's *Collinsia alba* as a synonym. This philosophy has held through all modern treatments of *Collinsia verna* (e.g., POWO 2021).

Discussion

The lack of attention in the literature concerning all-white forms of *Collinsia verna* can be partly attributed to the form's apparent rarity. It may be postulated that the white form results from a combination of recessive alleles. *Collinsia verna* reproduces by a combination of outcrossing and selfing (Kalisz 1989). It is known that insect pollinators discriminate against white phenotypes when white flowers are rare in populations (Waser and Price 1983; Clegg and Durbin 2000). There is research that indicates a lack of pollination drives delayed selfing in *Collinsia verna* (Kalisz *et al*. 1999). It would seem that selfing would mitigate pollinator discrimination against the white form, but confirming this will require long term observations. It is not clear what other reproductive factors may contribute to the observed rarity of this form within a large population of the typical species.

Future investigation will include determining if examples of the white form will persist at this site in the following growing season. It proved impractical to obtain a collecting permit before the plants senesced in 2021. The authors will pursue the future collection of a specimen for deposit in the Morton Arboretum herbarium (MOR), should the white form reappear in 2022.

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Newly Documented Populations of Two State Endangered *Carex* Species in Lake County, Illinois

Mark Kluge[1] and Kathleen Marie Garness[2]

Botanical nomenclature: Wilhelm and Rericha (2017)

***Carex formosa* Dewey (CYPERACEAE)**

Carex formosa was first documented in Lake County, Illinois with a collection by Jane and John Balaban on July 1, 1992 (MOR 108106, Table 1). This collection was from a degraded habitat, at the edge between a *Rhamnus cathartica* invaded flatwoods and a mowed right-of-way (J. Balaban, personal communication, January 6, 2021). The Balabans previously found the species in Cook County on June 22, 1992, its first record in Illinois (MOR 108147, Table 1). *Carex formosa* was subsequently designated an Illinois endangered species, restricted in the state to Cook and Lake counties (Nÿboer and Ebinger 2004). No more recent Lake County occurrences have been recorded (Illinois Natural Heritage Database 2021).

There are five extant naturally occurring populations of *Carex formosa* in Cook County, including the initial discovery site. Three of these sites are represented by collections (Table 1). A sixth population in a degraded Cook County woodland was extirpated as of 2013 (Kluge and Leavens, in preparation).

The original Lake County site had not been resurveyed since 1992. This site was recently visited (May 23, 2021) during field data collection for a detailed conservation assessment of *Carex formosa* in Illinois. No *Carex formosa* plants were found in this degraded habitat, and this population is now considered extirpated (Kluge and Leavens, in preparation).

Carex formosa was observed in two places at a second Lake County Forest Preserve site in 2013, but no voucher specimen was preserved (Ken Klick and Matt Ueltzen, personal communication, May 27, 2021). A survey of this site was performed on May 27, 2021. One population could not be relocated. A canopy opening project at the location of this population, performed in 2003 to facilitate more light to reach the ground layer, apparently aided the aggressive growth of *Fraxinus nigra* seedlings and briar thickets, perhaps contributing to decline in this population. The flush of woody seedlings was also likely stimulated by the emerald ash borer causing further mature tree mortality. However, the second population at the site was relocated during the survey in a flatwoods habitat approximately 800m east of the Des Plaines River. This population is native to the site, growing in a matrix of remnant vegetation.

With the concurrence of the landowner, the authors collected a specimen from this population on June 15, 2021 (MOR 187082). An extensive list of associated species was recorded: *Agastache scrophulariifolia, Agrimonia gryposepala, Allium canadense, Amphicarpaea bracteata, Caltha palustris, Carex bromoides, C. cristatella, C. davisii, C. gracillima, C. grayi, C. lupulina, C. squarrosa, C. stipata, C. tenera, C. vulpinoidea, Cinna arundinacea, Cornus racemosa, Cryptotaenia canadensis, Dioscorea villosa, Dryopteris* sp., *Elymus virginicus, Festuca subverticillata, Fraxinus nigra, Galium concinnum, Geranium maculatum, Geum canadense, Glyceria striata, Helianthus* sp., *Impatiens capensis, Iris virginica* var. *shrevei, Micranthes pensylvanica, Oxypolis rigidior, Parthenocissus* sp., *Penstemon calycosus, Quercus bicolor, Q. macrocarpa, Q. rubra, Ribes americanum, Rosa setigera, Rudbeckia laciniata, Sanicula odorata, Scirpus pendulus, Smilacina stellata, Smilax ecirrhata, Solidago canadensis, Thelypteris palustris, Thalictrum dasycarpum, Toxicodendron radicans,* and *Zizia aurea.* The total population of *Carex formosa* in these wet woods was estimated at 50 plants.

Significance: The previously recorded Lake County population of *Carex formosa* is now extirpated. To the authors' knowledge, our new record is the only currently persisting population of this species in Lake County and one of only six extant naturally occurring populations in Illinois. *Carex formosa* remains listed as state-endangered (Illinois Endangered Species Protection Board 2020).

***Carex intumescens* Rudge (CYPERACEAE)**

S. B. Mead (1846) published the first record of *Carex intumescens* in Illinois (Hancock County). The Han-

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Table 1: Herbarium specimens reviewed for this study.

Species	Collector/ Date	Location	Specimen Accession #	Portal URL
Carex formosa	Balaban, J. July 1, 1992	Lake Co., IL	MOR 108106	(physical specimen examined)
Carex formosa	Balaban, J. June 22, 1992	Cook Co., IL	MOR 108147	(physical specimen examined)
Carex formosa	Milde, M. July 17, 1995	Cook Co., IL	MOR 127721	(physical specimen examined)
Carex formosa	Wilhelm, G., & L. Rericha June 19, 2015	Cook Co., IL	MOR 180899	(physical specimen examined)
Carex intumescens	Johnson, L. N. May 30, 1890	Cook Co., IL	Putnam Museum and Science Center [no number]	https://vplants.org/portal/index.php
Carex intumescens	Umbach, L. H. June 11, 1897	Cook Co., IL	Field Museum Herbarium 86312	https://collections-botany.fieldmuseum.org
Carex intumescens	Jones, M. May 20, 1985	Cook Co., IL	MOR 153419	(physical specimen examined)
Carex intumescens	Milde, M. August 4, 1994	Cook Co., IL	MOR 126150	(physical specimen examined)
Carex grayi	Evers, R. A. May 25, 1954	Livingston Co., IL	ILLS 00021072	https://vplants.org/portal/index.php
Carex grayi	Bennett, H. R. July 2, 1955	Cook Co., IL	ILLS 00021023	https://vplants.org/portal/index.php

cock County occurrence is extirpated; Kibbe (1952) and Myers and Henry (1976) stated there were no later records in the county. L. N. Johnson made the first collection in Cook County in 1890 (vPlants 2021, Table 1). Jones and Fuller (1955) cited early collections in Cook County by Umbach in 1897 (Field Museum 2021, Table 1), and Cowles in 1908 as well as a Peoria County record by Brendel (n.d.). Mohlenbrock and Voigt (1957) documented a 1952 Johnson County collection, noting that *Carex intumescens* had not been found in the state since 1908. Winterringer and Evers (1960) cited a 1955 Cook County record (later annotated to *Carex grayi*, vPlants 2021, Table 1) and the 1952 Johnson County record. *Carex intumescens* was designated an Illinois endangered species in 1981, based on the erroneous 1955 Cook County record along with records from Alexander and Johnson counties in southern Illinois (Sheviak and Thom 1981). Sheviak and Thom (1981) also listed a Livingston County specimen, later annotated as *Carex grayi* (vPlants 2021, Table 1).

The rediscovery of *Carex intumescens* in Cook County occurred when M. Jones collected a voucher specimen in 1985 (MOR 153419, Table 1). Another collection was made at a second Cook County site in 1994 (MOR 126150, Table 1). Currently, occurrences in far southern Illinois have been recorded from Alexander (Basinger *et al*. 1997), Jackson, Johnson, Massac, Pope, Pulaski, Saline, and Union counties (Illinois Natural Heritage Database 2021). Thus, *Carex intumescens* has a widely disjunct distribution in the state. Bowles *et al*. (1991) cited Adams County in western Illinois, but this is not reflected in the Illinois Natural Heritage Database; we could not trace any corresponding specimen.

During August 6-7, 2021, a search was made for this species in a Lake County forest preserve, based on a 2006 sight record (Illinois Natural Heritage Database 2021). This site contains swampy flatwoods habitat appropriate to the species (Wilhelm and Rericha 2017). *Carex intumescens* was located during the survey, and its identification confirmed by Gerould Wilhelm of Conservation Research Institute and Paul Marcum of the Illinois Natural History Survey via field photographs. Approximately 15 fruiting plants were located while exploring only a portion of the suitable habitat; a voucher specimen was obtained with the concurrence of the landowner and deposited with Morton Arboretum (MOR 187083).

The local habitat is a seasonal streambed that contains a rich assortment of native wetland and low woods flora. Associates of this native population of *Carex intumescens* include: *Acer saccharinum*, *Amphicarpaea bracteata*, *Asclepias incarnata*, *Boehmeria cylindrica*, *Carex bromoides, C. cristatella*, *C. lupulina*, *C.*

vulpinoidea, *Cephalanthus occidentalis, Cicuta maculata*, *Elymus virginicus*, *Eupatorium perfoliatum*, *Fraxinus nigra*, *Glyceria striata*, *Helenium autumnale*, *Impatiens capensis*, *Iris virginica* var. *shrevei*, *Lobelia cardinalis*, *Lycopus americanus*, *Lycopus uniflorus*, *Lysimachia ciliata*, *Muhlenbergia glomerata*, *Oxypolis rigidior*, *Pedicularis lanceolata*, *Penthorum sedoides*, *Persicaria hydropiperoides*, *Prunella vulgaris* var. *lanceolata*, *Quercus bicolor*, *Ribes americanum*, *Scirpus atrovirens*, *Scutellaria lateriflora*, *Solidago gigantea*, *Thalictrum dasycarpum*, *Ulmus rubra*, and *Zizia aurea*.

Significance: This collection vouchers a county record for *Carex intumescens* in Lake County, Illinois. This species grows in scattered counties in northeastern and far southern Illinois but is considered rare in the state (Mohlenbrock 2011); it remains listed as state-endangered (Illinois Endangered Species Protection Board 2020).

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ERRATUM

In August 2019, we were contacted by Dr. John Kartesz, concerning the article 'Illinois Flora Updates: New Distribution Records and Other Noteworthy Finds' in *Erigenia* 27 (Fall 2018, pages 25-30). In that article, it was stated "they (USDA Plants and BONAP) have their limitations as they depend on either published sources or reports provided by contributors" (page 27). Dr. Kartesz commented that the primary source of the distribution records in BONAP (and USDA Plants) is through his detailed assessment of published records and specimens from virtually every major botanical institution across North America; only a very small percentage are contributed by others.

We apologize for any confusion or unintended offense. For those who would like more information about Dr. John Kartesz and the BONAP project, you can visit the BONAP website: http://www.bonap.org/

Illinois Native Plant Society Flora Update Committee (email: eulaszek@illinois.edu)