

EFFECTS OF BURN SEASON ON BEE AND FLORAL COMMUNITY IN TALLGRASS PRAIRIES,
AND THE USE OF MUSEUM COLLECTIONS DATA

BY

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THESIS

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ABSTRACT

Prescribed fires (controlled burns) in tallgrass prairie systems are a common land management technique used across the United States to maintain species diversity. Burns are conducted either in the winter or early spring (dormant season) or in late summer and early fall (growing season). Prairies are rich in diverse bee taxa, including many solitary and social species. It is unknown if dormant season or growing season burns differentially affects the following year's bee community and their resources. Chapter 1 addresses the question of how fires affect bees in prairie fragments in Illinois. Understanding the effects of the different burn seasons will aid future pollinator- and bee-friendly land management and restoration projects. In 2016 and 2017, bees were collected from seven prairie sites in south-central Illinois using active netting, pan traps, and vane traps. Overall, both burn seasons increased the amount of bare ground compared to unburned areas, but growing season burns contained greater total area of bare ground than dormant season burns. This resulted in an increase in abundance of below-ground nesting bee species after growing season burns. The decrease in nesting material for above-ground nesting bees in the burned treatments resulted in a lower proportional abundance of those species compared to areas that were not burned. However, comparing the dormant and growing seasons of burn, there was no effect on the overall bee community. Amount of semi-natural area in the landscape and the matrix surrounding each prairie fragment may play a larger role in maintaining stable bee communities in highly fragmented habitats. Land managers can burn during both seasons knowing that bee communities will not be adversely affected.

Chapter 2 utilizes the museum specimens housed at the Illinois Natural History Survey (INHS), University of Illinois, to address several issues concerning the use of

museum collections to detect species distribution shifts and declines. Many changes to species distributions often occur over long time scales, where museum records are the only source of information regarding the historical occurrences of species. Efforts to digitize museum collections aids in identifying areas and species for conservation, but sampling biases and differences in specimen deposition into museum collections by various collectors over time, data entry errors, and misidentification of specimens can limit the accuracy of data collected from museums. This chapter describes the activities of compiling an updated Illinois bee species checklist of 455 species, correcting errors found in the INHS online database, and identifying potential new county and one state records (*Diadasia enavata* Cresson, 1872) for Illinois from the collections conducted in Chapter 1. Continued support for natural history museums across the country will allow future research on the impacts to ecosystems caused by human and natural influences.

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CHAPTER 1: EFFECTS OF BURN SEASON ON BEE AND FLORAL ABUNDANCES, SPECIES RICHNESS, AND NEST GUILDS IN TALLGRASS PRAIRIES

Abstract

Prescribed fires, or controlled burns, in tallgrass prairie systems are a common land management technique used across the United States to maintain species diversity. Dormant season and growing season burns are currently in use, and their fire behavior can have differential effects on ecosystem biodiversity. Prairies are rich in diverse bee taxa, including many solitary and social species. It is unknown if dormant season or growing season burns differentially affects the following year's bee community and their resources. Bees that nest in the soils (below-ground nesters) are protected from the heat of a dormant season fire, however, bees that construct nests above ground in stems or on soil surfaces (above-ground nesters) are more likely to be negatively impacted by dormant season burns both directly by being consumed in the fire fuel as they overwinter in stems and indirectly from the decrease in nesting resources. In 2016 and 2017, bees were collected from seven prairie sites in south-central Illinois using active netting, pan traps, and vane traps and measurements of plant, flower and ground cover were taken. Growing season burns contained greater total area of bare ground than dormant season burns which could benefit ground-nesting bees and may explain the increase in abundance of below-ground nesting bee species after growing season burns. The decrease in nesting material for above-ground nesting bees in the burned treatments may be responsible for the observed lower proportional abundance of those species compared to areas that were not burned. However, comparing the dormant and growing seasons of burn, there was no effect on the overall bee abundance and richness. Amount of semi-natural area in the landscape and the matrix surrounding each prairie fragment may play a larger role in maintaining stable bee

communities in highly fragmented habitats. Land managers can burn in a mosaic pattern during both seasons, rotating the fragments burned between years and leaving refuge area, without adversely affecting bee abundance and species richness.

Introduction

Lightning-ignited fires were historically the main driving forces that shaped much of the terrestrial landscapes (Cooper 1960). These summer growing season fires were later harnessed by Native Americans to clear areas for prairie and bison grazing (Pyne 1986). After more than a century of fire suppression altered landscapes across North America by allowing forest succession and reducing fire-adapted species (Cooper 1960; Higgins 1984), prescribed burns were reincorporated into land management. These prescribed burns occur largely in the winter dormant season and have been critical for increasing flora and fauna biodiversity in fire-maintained habitats such as tallgrass prairie (Sparks et al. 1998; Panzer and Schwartz 2000). Despite renewed interest in restoring and maintaining the threatened tallgrass prairies in the Midwestern United States (Leach & Givnish 1996; Packard & Mutel 1997) many questions remain about how the change in burn season, from historic growing season fires to prescribed dormant season burns, affects prairie biodiversity.

Dormant season burns are those conducted during the winter months between late December after vegetation has gone into dormancy and early March before spring regrowth. These fires burn at higher intensities, consume most of the vegetation biomass, travel at quicker rates, increase late-season grass and forb production, and lower total soil moisture (Howe 1994; Towne and Craine 2014). Conversely, growing season burns are conducted during the late summer and fall months between August and October when vegetation is still actively growing, and promote early-flowering forb production (Howe 1994; Towne and Kemp 2003). Despite the similarity between growing season burns and the historic timing of lightning-ignited fires (Higgins 1984), many land managers of

tallgrass prairie systems are still not incorporating this burn season in their management (Harmon-Threatt and Chin 2016). The reluctance to adopt growing season burns is driven in part by concern and lack of empirical data for how these two seasonal burn management strategies compare in terms of affecting higher trophic levels.

Multiple studies have examined the effects of prescribed burns on a variety of organisms (Ford et al. 1999; Grant et al. 2011), but most of these studies did not analyze burn season. One of the few that directly compared dormant and growing season burns found that total arthropod abundances increased more after a growing season burn compared to the dormant season burn (Johnson et al. 2008). Other studies have found that arthropod groups respond differentially to burn season (Panzer and Schwartz 2000; Moranz et al. 2013; Swengel and Swengel 2013; Polchaninova et al. 2016), yet none have assessed the effects on native bees (Hymenoptera: Apoidea: Anthophila), a group of organisms responsible for a majority of agricultural and wild flower pollination (Neff and Simpson 1993; Winfree et al. 2008). Moreover, the greatest differences are expected to have a higher detectability immediately following a burn, where bees overwinter in and around prairie fragments and require various resources near their overwintering nest. Several studies have determined that the bee community reaches pre-burn diversity three to five years post burn (Rutgers-Kelly et al. 2013), yet observing and sampling the year after a burn has not been conducted. In this study, I consider how bees may respond to differences in burn season during the first year after a burn based on their reliance on floral food resource and vegetation structure for nesting resources.

Native and often solitary bee species can be broadly grouped into two nesting guilds based on nest substrate preferences; bees that only nest in the soils are termed below-

ground nesting bees, and bees that nest in stems, on the ground surface, and pre-excavated cavities are termed above-ground nesting bees (Michener 1974). Fire is known to clear debris and increase bare ground which is important for below-ground nesting bees (Sparks et al. 2002; Potts et al. 2005) and is presumed to negatively affect above-ground nesting bees by reducing standing vegetation for potential nests. Fire may also directly kill above-ground nesting bees during the dormant season while below-ground nesting bees are mostly protected from fire heat (Cane & Neff 2011). However, few studies have examined how burn season, which can alter fire intensity and vegetation structure, affect bees within these nesting guilds. Understanding how the two previously described burn seasons affect the native bee communities, particularly in the year following the burn event, is important for guiding future management strategies.

My study includes two main objectives to address the knowledge gap in understanding effects on bee communities the year after dormant and growing season burn treatments:

- a) examine the correlation between resource availability (nesting and foraging) and wild bee abundance and species richness, and
- b) measure effects on the above and below-ground nesting guilds.

Because many restorations are currently focused on enhancing pollinators and pollination services, this study should guide pollinator- and bee-friendly restoration and management efforts.

Methods

Study Area

The study was conducted on the fragmented tallgrass prairie landscape of south-central Illinois. The climate of this area is characterized by hot humid summers, with temperatures between May and August (when bees are most active) ranging from 16.34 ± 2.22 °C to 28.99 ± 3.11 °C and summer rainfall of 1.19 ± 1.57 cm (NOAA 2017). The mesic tallgrass prairie sites were surrounded by a mix of oak-hickory forested areas, wetlands, agricultural fields, roads, and small rural establishments.

Prairie Site Selection

In 2016 and 2017, prairie fragments with dormant and growing season burn treatments within 1 km distance were selected and paired into blocks to maintain vegetation and soil characteristics (Figure 1.1). Burned treatments within the blocks were separated by at least 350 m, and each block was separated by a distance greater than 1 km. In 2016, a prairie section that was left unburned during the previous three years was included in each block (Rutgers-Kelly et al. 2013). A 0.33 ha sampling unit was established within each treatment, with 12 units sampled in 2016 and six units sampled in 2017 for a total of 18 units within the Illinois counties of Effingham, Fayette, Jasper, and Marion (Table 1.1). To limit variations in temperature and the possibility of species traveling between sites, all sampling units within a block were sampled for bees and vegetation on the same day. I sampled each sampling unit once every four weeks between the months of May and August for a total of four search and capture netting hours and 32 passive sampling hours per sampling unit.

Ground Cover and Floral Community Data Collection

Ground cover was estimated monthly for each sampling unit using the average of twenty-five 0.25 m² quadrats thrown randomly along a central 100 m transect. Stems of plants that originated within quadrats were included in vegetation and cover counts to obtain accurate measurements. Percent bare ground (nothing covering the soils), dead vegetation (non-living material), grass, forb, and moss were estimated for each quadrat and then averaged over the twenty-five quadrats within each sampling unit.

In each quadrat, the number of flower heads (individuals or inflorescences) of each flowering species in bloom was recorded as an estimate of available flower resources. Due to the difficulty and inefficiency in counting large numbers of small individual flowers, inflorescences were instead counted for several plant species (i.e. *Solidago* spp. and *Verbena hastata*).

Bee Data Collection

Both passive and active sampling techniques were used to sample the bee community in each unit. Along the center transect, colored passive pan (Solo Soufflé brand 3.14 oz) and blue vane traps (BioQuip) were deployed before 8:00 and collected after 17:00 at five evenly spaced stations (Figure 1.1). At each station, one vane trap and three pan traps (ACE ® Glo Spray fluorescent blue, white, and yellow) were placed 1 m above the ground, and three pan traps were placed at ground level. Both trap types were filled with a Dawn® blue brand soap and water solution. Specimens were strained on site and placed into Whirl-Paks® Brand (Nasco 4 oz bags) with 70% ethanol for transport. Bees were actively hand-netted from flowers for 30 minutes of search and capture, excluding handling time, during the morning (between 8:00 and 11:00) and afternoon (between 14:00 and

17:00) within the sampling unit. Captured bees were euthanized by placing them into cyanide jars corresponding to the flower species. The use of three sampling methods lowers the potential biases attributed to each method to give a comprehensive representation of the bee species present within each sampling unit (Roulston et al. 2007, Geroff et al. 2014).

To address the effect of burn season on bee nesting guilds, a literature review was conducted on each species recorded in this study to determine nesting strategy. Several species did not have data regarding their nesting ecology, but presumptive nesting strategy based on the other species within the same genera were used (*indicated in Table A.1 with **). Because the nest strategy of parasitic bee species depends on their host species, these parasitic species were excluded from the nesting guild analysis.

Analysis

The averaged relative percent bare ground and total cover (grass, forb, moss, and dead vegetation combined) was analyzed using generalized linear mixed-effects model (GLMM) with binomial distribution. Akaike Information Criterion (AIC) and significance of interaction terms were used to choose the best model, which had treatment and month as fixed effects, and block as a random effect. A two-sided Tukey post-hoc test was used to determine pair-wise comparisons between the three treatments. The variables for this model were used for all other models presented below, and in all cases the variable of flower head abundance was excluded due to a higher AIC and lack of significance.

Total flower head abundances were analyzed using GLMM. Bee abundances and species richness were also analyzed using GLMM, and the relative proportion of abundances and species richness of above and below-ground nesting species of bee were

analyzed using GLMM with binomial distribution. Bee specimens without species identification were excluded from the analyses. The statistical program RStudio (RStudio, Inc., version 1.0.153) was used for analysis along with the packages *lme4* (Bates et al. 2015, version 1.1-13), *multcomp* (Bretz et al. 2010, version 1.4-7), and *vegan* (Oksanen et al. 2007, version 2.4-4).

Results

Ground Cover and Floral Community

All three treatments had significantly different proportions of bare ground (Figure 1.2), with growing season burn treatments having the most compared to dormant season and unburned treatments (Table 1.2). Bare ground significantly decreased ($df=62$, $t=-6.599$, $p<0.001$), and flower abundances increased ($df=62$, $t=3.441$, $p=0.001$) over the season. There were no differences in flower abundances among the three treatments (Table 1.2).

Bee Community

A total of 7,116 bee records identified and verified to 117 species, comprising 33 above-ground nesting, 84 below-ground nesting, and 10 parasitic bee species (Table A.1), 53 of which were caught with only one of the three trapping methods. Bee species richness was not affected by burn treatment (Table 1.2), but increased throughout the season ($df=62$, $t=12.857$, $p<0.001$). Bee abundance was greater in the growing season treatment compared only to the unburned treatment ($df=62$, $z=-2.746$, $p=0.016$; Figure 1.3) and also increased throughout the season ($df=62$, $t=4.962$, $p<0.001$), though not as steeply as species richness.

The proportional species richness of above-ground to below-ground nesting bees decreased through the season ($df=62$, $t=-16.848$, $p<0.001$), but was not different between the three treatments overall (Table 1.2). The seasonal decrease was sharper for proportional abundances ($df=62$, $t=-27.882$, $p<0.001$), and there were higher proportions of above-ground nesting bees in unburned treatments compared to both burned treatments (Figure 1.4, Table 1.2). To see if above or below-ground nesting bee species richness and abundance were driving any shifts in these proportions, additional GLMM were conducted on each nesting guild separately. The abundance of above-ground nesting bees changed little through the season ($df=62$, $t=1.151$, $p=0.254$), while below-ground nesting bee abundances increased ($df=62$, $t=7.114$, $p<0.001$) with greater abundances captured in the growing season treatments compared to the unburned treatments (Table 1.2). Species richness of below-ground nesting bees increased over twice as much as above-ground nesting bees through the season ($df=62$, $t=13.760$, $p<0.001$; $df=62$, $t=5.610$, $p<0.001$), but neither were different between treatments (Table 1.2).

Discussion

While both burn seasons resulted in greater proportions of bare ground, the growing season burns had the greatest increase, and thus a greater amount of available nesting substrates for below-ground nesting bees (Potts et al. 2005). One effect of growing season burns is to reduce the size and amount of grasses (Howe 2011), which could increase the amount of total bare ground (Ford & Johnson 2006). Alternatively, fire intensity and the rate of spread can be influenced by the weather conditions prior to and during the day of a prescribed burn (Fang et al. 2015), and the unseasonable amounts of

late-season precipitation during the study period (MRCC 2017) which could have increased vegetation moisture content, preventing dormant season treatments from reaching and/or maintaining the stereotypical high intensity fires.

While other studies found an increase in forb production after growing season burns compared to dormant season burns (Howe 1994; Copeland et al. 2002), the current study found no difference in flower abundances (*also see* Fynn et al. 2004; Towne & Craine 2014). Bare ground created by fires can increase seed germination rates (Maret & Wilson 2005) and alter flower phenology (Rau et al. 2008). Flower community is additionally mediated by the available seed bank within the prairies (Dalglish & Hartnett 2009). Thus, significant changes in forb number may not appear the year immediately following a prescribed burn.

A reduction in the proportion of above-ground nesting bees in both burn treatments compared to unburned treatments was similar to that found by a literature review (Williams et al. 2010). However, when comparing dormant and growing season burns, the burn season did not result differences in proportional abundance of above-ground to below-ground nesting bee species. Above-ground nesting bees were most abundant in unburned treatments, which left standing vegetation and provided nesting sites as well as allowed the development and emergence of the previous winter's overwintering bees. Below-ground nesting bees were most abundant in the growing season treatments only compared to unburned treatments, possibly in response to the greater available bare ground for nesting sites.

Other researchers found differential effects of burn season based on taxonomic grouping and species-dependent responses of other arthropods (Panzer 2002; Johnson et

al. 2008). In contrast, overall bee species richness and abundance did not differ between the two burn seasons in this study. Although no differences were observed between the bee communities in dormant and growing season burn treatments, growing season burns may increase population sizes of below-ground nesting bees by providing more bare ground for potential nest sites. Nesting is considered a primary limiting factor for many bees (Potts et al. 2005), so providing appropriate nesting substrates could help increase population sizes.

Management Suggestions

Conducting prescribed burns regardless of burn season in a patch-burn mosaic pattern and rotating burns within a prairie fragment increases both the available bare ground to support below-ground nesting bee species as well as leaves refuge area to maintain above-ground nesting bee populations, thus increasing overall bee diversity. Bees nest in a wide variety of substrates, from disturbed flat soils to rotting wood, and the amount of forest and semi-natural habitat near prairies can provide required nesting resources (Banaszak 1992; Fitzpatrick et al. 2007; Rubene et al. 2015). Due to the fragmented landscapes, the sampling units in this study may have been close enough to other semi-natural habitat and unburned portions of prairie and allowed for quick recolonization within the following year after a burn. Creating a heterogeneous landscape within and surrounding tallgrass prairie fragments may stabilize the bee communities regardless of burn season (Steffan-Dewenter and Tscharntke 2001; Panzer 2002).

Not only would a rotational mosaic burning pattern increase the available nesting substrates for bees, finding similar effects of both burn seasons on bees allows for a greater timeframe for management opportunities. This is particularly essential for regions which experience high variability in weather patterns that often make it difficult to conduct all

planned prescribed burns on time within a season in order to maintain biodiversity in fire-dependent ecosystems (Weir 2011). The increased management opportunities can accommodate other specific management goals, such as burning areas for the threatened species like the greater prairie chicken (*Tympanuchus cupido*). In these fragmented prairie habitats, either dormant or growing season burns can be used to increase tallgrass prairie management opportunities without negatively affecting native bees.

Future Directions

The current study adds to our understanding of how bees respond to prescribed fires in a system that is historically fire adapted and currently being maintained predominantly by prescribed fires. While the current results suggest little initial difference between dormant and growing season burns, questions remain regarding other variables in time and in space that could be influencing the bee community. Utilizing pre- and post-fire sampling over several years in both remnant and restored prairies will help identify potential lag times in bee and floral responses to fires. Measuring variables in the surrounding landscape (Rubene et al. 2015) and more closely tracking nesting substrate availability over time would further our understanding of bee responses to burn season.

Tables and Figures

Table 1.1: Locations of blocks and dimensions of sampling units during the 2016 and 2017 sampling year.

Block	Treatment	County	City	Name	Latitude	Longitude	Sample Plot Size (m)	Distance between stations (m)
1	Dormant	Effingham	Edgewood	12 Mile Tract 2	N38° 56.306'	W88° 38.551'	20x150	30
1	Growing	Effingham	LaClade	12 Mile Tract 3	N38° 52.238'	W88° 43.561'	20x150	30
1	Unburned	Effingham	Mason	12 Mile Tract 1	N38° 58.408'	W88° 35.981'	20x150	30
2	Dormant	Fayette	Farina	12 Mile Tract 4	N38° 50.603'	W88° 45.571'	20x150	30
2	Growing	Fayette	Farina	12 Mile Tract 5	N38° 49.326'	W88° 47.143'	20x150	30
2	Unburned	Fayette	Farina	12 Mile Tract 4	N38° 51.287'	W88° 44.734'	20x150	30
3	Dormant	Marion	Kinmundy	PRSNA Loy Tract	N38° 48.666'	W88° 48.428'	20x150	30
3	Growing	Marion	Kinmundy	PRSNA Loy Tract	N38° 48.976'	W88° 47.932'	20x150	30
3	Unburned	Marion	Kinmundy	12 Mile Tract 5	N38° 48.801'	W88° 47.795'	20x150	30
4	Dormant	Effingham	Altamont	Ballard Nature Center	N39° 04.029'	W88° 42.163'	30x100	20
4	Growing	Effingham	Altamont	Ballard Nature Center	N39° 03.665'	W88° 42.302'	30x100	20
4	Unburned	Effingham	Altamont	Ballard Nature Center	N39° 03.522'	W88° 42.562'	30x100	20
5	Dormant	Jasper	Bogota	PRSNA Fuson Tract	N38° 55.657'	W88° 14.799'	30x100	20
5	Growing	Jasper	Bogota	PRSNA Fuson Tract	N38° 55.478'	W88° 15.279'	30x100	20
6	Dormant	Jasper	Bogota	Gillespie Property	N38° 54.095'	W88° 15.546'	25x120	25
6	Growing	Jasper	Bogota	Gillespie Property	N38° 54.100'	W88° 15.294'	25x120	25
7	Dormant	Marion	Kinmundy	Forbes State Park	N38° 44.034'	W88° 47.369'	30x100	20
7	Growing	Marion	Kinmundy	PRSNA Soldner Tract	N38° 46.034'	W88° 47.937'	30x100	20

Table 1.2: Habitat and bee variables in response to burn treatment. Tukey pair-wise comparisons conducted after GLMM. Z-scores are presented, and significance of $\alpha < 0.05$ are bolded.

Bare Ground		Flower Abundance	
GS-DS	2.486 (0.031)	GS-DS	0.887 (0.647)
UB-DS	-17.373 (<0.001)	UB-DS	0.900 (0.639)
UB-GS	-18.513 (<0.001)	UB-GS	0.143 (0.989)
Bee Species Richness		Bee Abundances	
GS-DS	1.143 (0.486)	GS-DS	1.539 (0.271)
UB-DS	-0.959 (0.602)	UB-DS	-1.471 (0.303)
UB-GS	-1.932 (0.129)	UB-GS	-2.746 (0.016)
Proportion Above-Ground Nester Species Richness		Proportion Above-Ground Nester Abundance	
GS-DS	1.716 (0.197)	GS-DS	0.905 (0.636)
UB-DS	0.757 (0.728)	UB-DS	4.960 (<0.001)
UB-GS	-0.642 (0.796)	UB-GS	4.228 (<0.001)
Above-Ground Nester Species Richness		Above-Ground Nester Abundance	
GS-DS	0.878 (0.653)	GS-DS	0.664 (0.783)
UB-DS	-1.000 (0.575)	UB-DS	-0.986 (0.584)
UB-GS	-1.730 (0.193)	UB-GS	-1.530 (0.275)
Below-Ground Nester Species Richness		Below-Ground Nester Abundance	
GS-DS	0.573 (0.834)	GS-DS	1.861 (0.149)
UB-DS	-0.871 (0.658)	UB-DS	-1.380 (0.349)
UB-GS	-1.359 (0.361)	UB-GS	-2.906 (0.010)

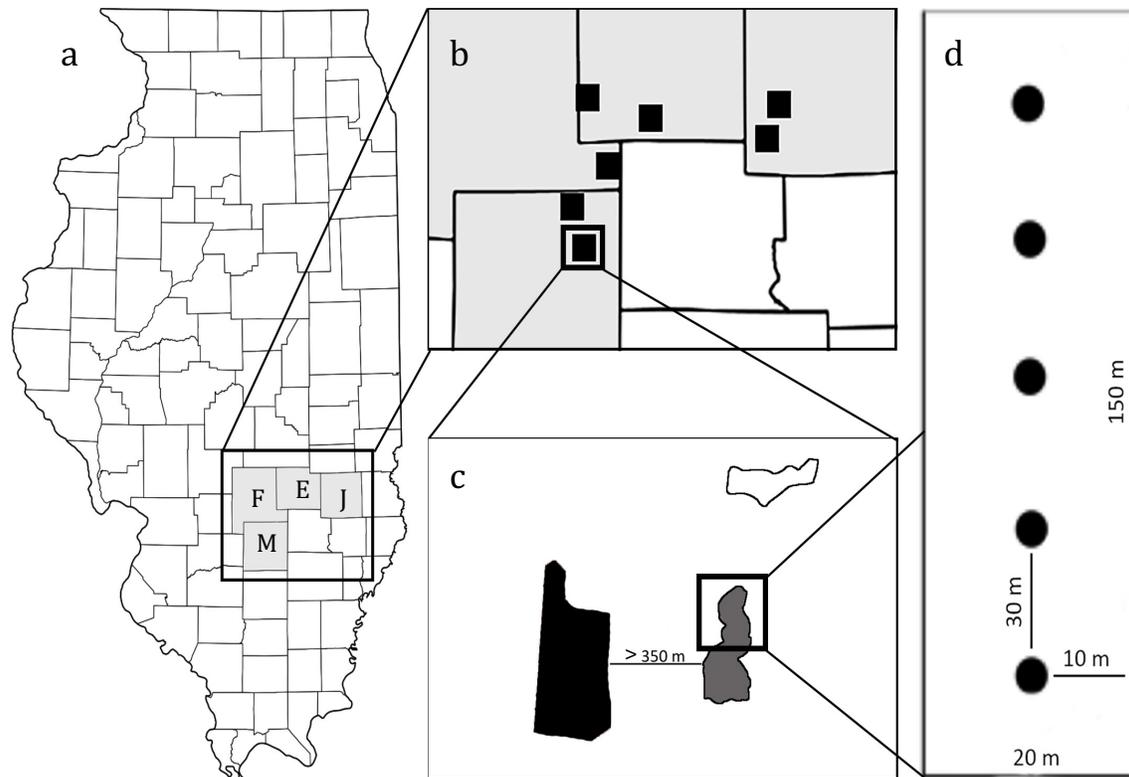


Figure 1.1: Diagram of Study Location. a) Effingham (E), Fayette (F), Jasper (J), and Marion (M) Counties were sampled. This diagram depicts b) the location of seven blocks used in this study as black boxes, c) an example of prairie fragments that were in each block, each with a different burned treatment (i.e. white is dormant season, grey is growing season, and black is unburned), and d) an example of sampling unit dimensions with black circles representing stations.

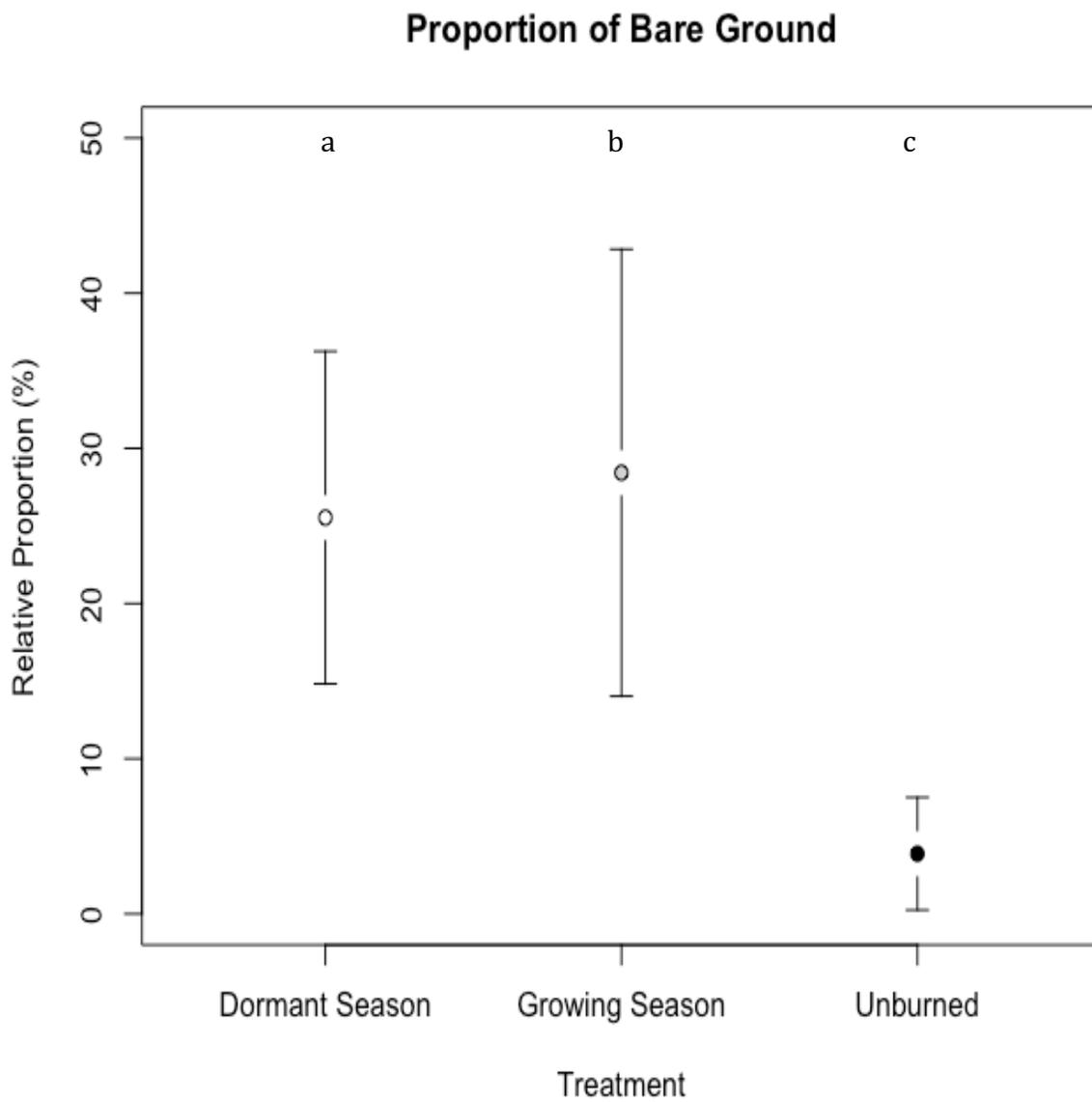


Figure 1.2: Relative proportion of bare ground in each treatment. Each treatment had a different proportion of bare ground availability. Letters indicate significant differences between treatments (see Table 1.2).

Bee Abundances

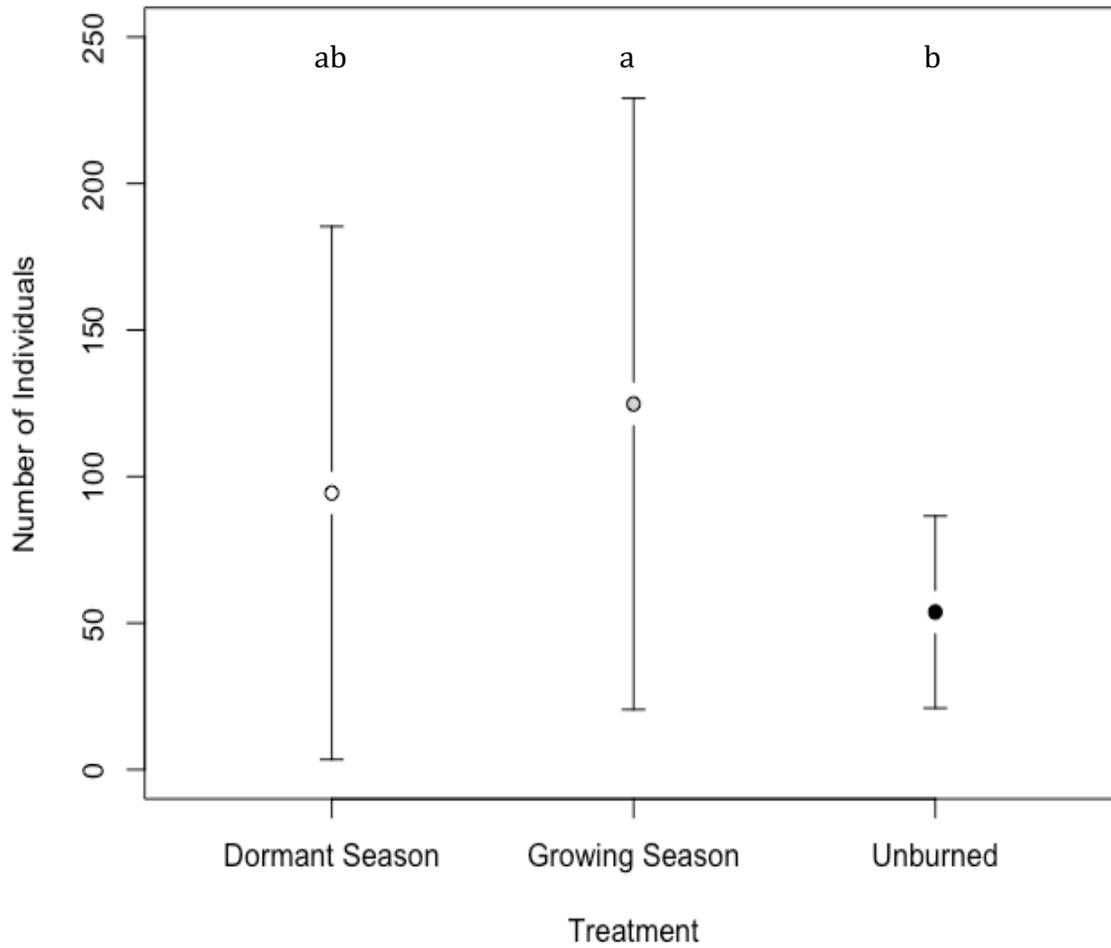


Figure 1.3: Bee abundances are greatest in growing season treatments, followed by dormant season treatments, and lowest in unburned treatments. Letters indicate significant differences between treatments (see Table 1.2).

Proportion of Above-Ground Nesting Bee Abundance

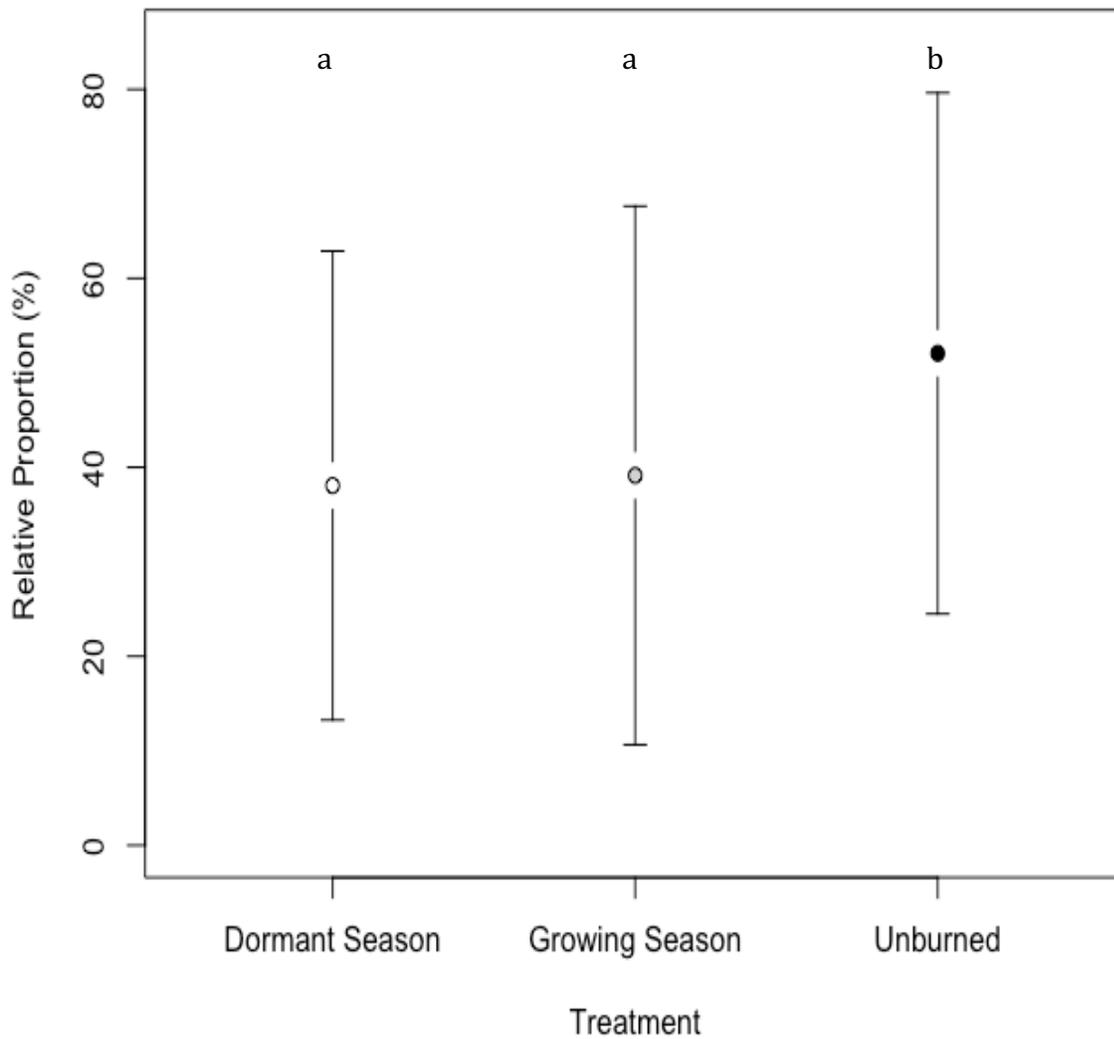


Figure 1.4: Proportion of above-ground nesting bee abundances in each treatment. Proportional abundances are greatest in the unburned treatment compared to both the dormant and growing season treatments. Letters indicate significant differences between treatments (see Table 1.2).

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CHAPTER 2: PRELIMINARY ILLINOIS BEE SPECIES CHECKLIST AND USE OF MUSEUM COLLECTIONS

Abstract

Climate change and landscape alterations may influence biodiversity by shifting species distributions or causing local extirpations. Because these changes may only occur over long periods of time, museum records are needed in order to track such changes. Bees are a group of organisms known to be in decline globally, but tracking regional shifts is difficult. Particularly in Illinois, where there have been significant alterations to the landscape, no bee species checklist is available to compare recent collecting efforts. I used museum specimens housed at the Illinois Natural History Survey (INHS), University of Illinois, to investigate several issues concerning the use of museum collections to detect species distribution shifts and declines. Many changes to species distributions often occur over long time scales, where museum records are the only source of information regarding the historical occurrences of species. Museum collections have digitized specimens and labels to aid in identifying areas and species for conservation. Inherent in these collection databases are sampling biases and differences in specimen deposition into museum collections by various collectors over time, data entry errors, and misidentification of specimens. After identifying and correcting errors, a preliminary state checklist of 455 bee species was completed. Additional comparison of this checklist to the recent collection described in Chapter 1 identified potentially declining species and new county and one state records (*Diadasia enavata* Cresson, 1872). Continued support for natural history museums across the country will allow further research on the impacts to ecosystems caused by human and natural influences.

Introduction

Climate change and landscape alterations may influence biodiversity by shifting species distributions or causing local extirpations (Biesmeijer et al. 2006; Miller-Struttman et al. 2015). However, because these changes can occur over long periods of time (Burkle et al. 2013), historical records are needed to provide baseline data on past species abundances and distributions. Previous work has used these valuable museum collections of historic records to identify whether species are shifting in distribution or potentially declining (Grixti et al. 2009; Kearns and Oliveras 2009; Cameron et al. 2011; Primack and Miller-Rushing 2012; Stockli et al. 2012). In most locations, historic sampling is often inconsistent through time, which makes it difficult to analyze distributions or obtain and improve known species lists for a region that would aid in future conservation planning.

To support conservation considerations for many species, museum collections have begun to digitize specimens and labels to allow for easier access to this wealth of information. There are still several limitations to using this information that stems from multiple sources. First, sampling protocols and deposition of specimens into museum collections are not standardized between individual collectors or time periods, providing incomplete data across time and space. Second, data entry errors occur when digitizing, which could result in improper analysis and conclusions. Third, many specimens need expert verification on species identification, and many specimens may have been misidentified or a single species may have been recently split into two separate species. Meticulous collections and curation of specimens are needed to provide a baseline for research and ensure taxonomic names are updated regularly. Nonetheless, museums play a

vital role in understanding species distributions, particularly for groups or taxa that are known to be declining.

Due to recent concern about global declines of bees (Hymenoptera: Apoidea: Anthophila), a taxon that plays a crucial role in crop and wildflower pollination (Potts et al. 2010; Albrecht et al. 2012), there have been several efforts to create bee species checklists to serve as baseline data for future research and monitoring as the landscape is altered by human activities (Pascarella et al. 2012; Zarrillo et al. 2016). The Midwest United States, particularly in Illinois, has experienced extensive landscape alterations driven by agricultural intensification over the past century (Leach & Givnish 1996; Packard & Mutel 1997; Iverson 1998). However, no bee species checklist is available for the state of Illinois. While Illinois is estimated to have between 300-500 different bee species (Rugg 2013; Chicago Botanical Gardens 2017), assessing the status of Illinois bees is hindered not only by a lack of consistent collections through time across the state but the absences of a reliable checklist of species.

As an example of how to utilize meticulous and consistently collected historical records, Marlin & LaBerge (2001) 1972 study and Burkle et al. (2013) 2009-2010 study compared their bee biodiversity sampling to a 1884-1916 collection effort by Charles Robertson in Carlinville, IL to document bee species presence and bee-plant associations shifts. Because the records were well-kept and the original collector consistently sampled over multiple years, Marlin & LaBerge (2001) found relatively similar bee species from 24 flowering plants after 75 years, while Burkle et al. (2013) were able to identify bee-plant association shifts and species extirpation after 120 years. However, such collections are few, and for larger regions, a wide range of collections through time and space are needed.

There are two objectives to this study: 1) generate a preliminary species checklist for Illinois bees based on the records housed at the Illinois Natural History Survey (INHS), University of Illinois, and 2) demonstrate the utility of an updated digitized collections record by comparing historic records and current collections for four Illinois counties. INHS contains specimens dating back to the late 1800's and contains a greater number of bee specimens as other museum collections (INHS contains almost 60,000 Illinois bee records, while pulling country-wide digitized bee records from Symbiota Collections of Arthropods Network (SCAN; <http://symbiota4.acis.ufl.edu/scan/portal/collections/>) contains 11,530 Illinois bee records), indicating that the records housed at INHS are representative of the total number of bee species present in Illinois. Additionally, several studies conducted in Illinois and deposited in INHS have an extensive focus on bee collections (Robertson 1929; Bouseman 1997; Marlin & LaBerge 2001; Burkle et al. 2013). This collection provides an ideal starting point to analyze bee distributions and provide an Illinois species checklist.

Methods

Identification of species list

A copy of the INHS Bee records from Illinois was obtained from the online database (INHS 2017). Before analyzing this data, several steps were needed to improve the quality of the INHS database (Figure 2.1). An initial list of species was generated after removing records with missing species information.

Using Discover Life (www.discoverlife.org) global maps and a literature review, each bee species in the preliminary Illinois list was researched to verify its presence in

Illinois and correct invalid taxonomic names and misspellings. Specimens in the collection that did not occur in Illinois were verified to determine collection location and correct the database where needed. Using the Integrative Taxonomic Information System (www.itis.gov) database of taxonomic names and a literature review, the recorded scientific names of seventy-seven species (Table B.1) in the INHS database were found to be invalid. Records containing invalid species names were recorded and updated in the INHS database copy to the valid species synonym listed on Discover Life (Table B.1), generating a final Illinois bee species checklist. Additional literature research is needed to determine the publication source before completing these updates in the online INHS database.

Database Comparison to Sampling in Four Counties

Records for Effingham, Fayette, Jasper, and Marion Counties were extracted from the updated INHS database to demonstrate one way to compare museum records by using a 2016-2017 collection (hereafter termed “recent collection”, see Chapter 1). Due to differential sampling efforts within museum records, species presence and absence was compared between the INHS checklist and the recent collection effort.

Results

Database Updates

The INHS database currently online (INHS 2017) contains 59,580 bee specimen records for Illinois, 45,885 of which had complete species identification information. 505 different species were recorded over 131 collecting years from 1875 to 2015 from all 102 counties of Illinois. Removing records that were found to have incorrect location

information or where valid scientific names were unverifiable (*Andrena chrysoceles* Kirby, 1802, one record) resulted in 464 bee species (45,813 records, 130 collecting years).

After correcting invalid Latin names, there are 455 unique species that have been recorded in Illinois and deposited in the INHS Insect Collections (Table 2.1). Fifty-eight of these species were only recorded once throughout Illinois (*indicated in Table 2.1*).

Database Comparison to Sampling in Four Counties

There were 88 bee species recorded in the INHS database for the four counties analyzed, in contrast to the 117 bee species recorded in the recent collection and the 455 species for the state of Illinois (Table 2.2). Sixty-five species were recorded in the recent collection that were not recorded in the four counties in the INHS database (*indicated in Table 2.2*), while 36 species were not resampled during the recent collection (*indicated in Table 2.2; Figure 2.2*). Nine species in the recent collection were not found to be recorded previously in Illinois (*indicated in Table 2.2*), with one species verified as a new state record (*Diadasia enavata* Cresson, 1872).

Discussion

This study generated a preliminary bee species checklist for Illinois of 455 different species based on the collections housed at INHS that will serve as a baseline for future conservation and monitoring efforts. The checklist reaffirms the commonly estimated species count for Illinois, yet it should be considered an underestimate of the total number of bee species recorded in Illinois. While it was beyond the scope of this analysis, searching other databases, such as the collections housed at the American Museum of Natural History and the Smithsonian Institution National Museum of Natural History, as well as records in

the Global Biodiversity Information Facility (www.gbif.org), may produce additional records from Illinois, though these are most likely few in number. Analysis of the studies, locations, collecting method, and time of year for the specimens deposited in the INHS may also reveal biases towards certain bee species, specific habitat types, or seasonality, thus identifying sampling areas that require more attention.

Uses of Museum Collections

The comparison of a recent collection to the INHS records from Effingham, Fayette, Jasper, and Marion Counties of Illinois identified 65 potential new county records and 36 species that may be declining within those counties. Several species in the recent collection were identified as having no previous Illinois record in the INHS database, and have been highlighted for further verification. Despite specific collecting efforts in these counties previously (Bouseman 1997), additional bee species were observed during the recent collecting effort. The potential new county records may be of species that were not previously detected due to differing sampling efforts, no voucher specimens taken of each species collected, or that specimens that are specific to the four Illinois counties are deposited in other museum collections. The checklist provides a starting point to continue work with other museum databases. Thirty-six species, however, were not detected during the recent collection that were previously recorded in the four counties analyzed. It is possible these species are declining or were present but not detected due to sampling differences. Tallgrass prairie fragments currently contribute to less than 0.01% of the total landscape of Illinois (Iverson 1998), and sampling various habitat types may detect those other bee species.

Diadasia enavata (Cresson, 1872) is a new Illinois state record, and potentially the first recorded east of the Mississippi River (Mike Arduser, *pers. comm.*). Verification of this record east of the Mississippi River was not completed prior to this study. This specimen would not have been identified as a new state records without a current museum collections database, demonstrating the need for updated historical records to recognize species distribution shifts as a potential result of climate change.

The product of meticulous sampling, record-keeping, and curation can be highly valuable to researchers and the general public, but curating the most up-to-date records requires constant attention. Bee taxonomy, and taxonomy in general, is often changing with the discovery of new species and the availability of genetic sequencing. In order to allow researchers to infer from collections, databases need to take into consideration these taxonomic changes. This effort takes time and money to provide researchers with accurate data. Here it was demonstrated that comparing recent collecting efforts to museum records can reveal potential species declines and highlight geographical areas for further research and conservation focus. Continued support for museums across the country will aid in furthering our understanding of the impacts to the ecosystem brought on by human and natural influences.

Tables and Figures

Table 2.1: Illinois Bee Species Checklist, carrot signs (^) denote INHS collection singletons.
Andrenidae
<i>Andrena accepta</i> (Viereck, 1916)
<i>Andrena agilissima</i> (Scopoli, 1770)
<i>Andrena aliciae</i> (Robertson, 1891)
<i>Andrena alleghaniensis</i> (Viereck, 1907)
<i>Andrena andrenoides</i> (Cresson, 1878)
<i>Andrena angustitarsata</i> (Viereck, 1904)^
<i>Andrena apacheorum</i> (Cockerell, 1897)
<i>Andrena arabis</i> (Robertson, 1897)
<i>Andrena asteris</i> (Robertson, 1891)
<i>Andrena atypica</i> (Cockerell, 1914)^
<i>Andrena auricoma</i> (Smith, 1879)
<i>Andrena banksi</i> (Malloch, 1917)
<i>Andrena barbara</i> (Bouseman & LaBerge, 1979)
<i>Andrena barbilabris</i> (Kirby, 1802)
<i>Andrena bicolor</i> (Fabricius, 1775)
<i>Andrena bimaculata</i> (Kirby, 1802)^
<i>Andrena bisalicyis</i> (Viereck, 1908)
<i>Andrena brevipalpis</i> (Cockerell, 1903)
<i>Andrena canadensis</i> (Dalla Torre, 1896)^
<i>Andrena carlini</i> (Cockerell, 1901)
<i>Andrena ceanothi</i> (Viereck, 1917)
<i>Andrena chlorura</i> (Cockerell, 1916)
<i>Andrena chromotricha</i> (Cockerell, 1899)
<i>Andrena commoda</i> (Smith, 1879)
<i>Andrena confederata</i> (Viereck, 1917)
<i>Andrena cragini</i> (Cockerell, 1899)^
<i>Andrena crataegi</i> (Robertson, 1893)
<i>Andrena cressonii</i> (Robertson, 1891)
<i>Andrena cristata</i> (Viereck, 1917)
<i>Andrena distans</i> (Provancher, 1888)
<i>Andrena dunningi</i> (Cockerell, 1898)
<i>Andrena eothina</i> (Linsley & MacSwain, 1961)
<i>Andrena erigeniae</i> (Robertson, 1891)
<i>Andrena erythrogaster</i> (Ashmead, 1890)
<i>Andrena erythronii</i> (Robertson, 1891)
<i>Andrena fenningeri</i> (Viereck, 1922)
<i>Andrena flexa</i> (Malloch, 1917)
<i>Andrena forbesii</i> (Robertson, 1891)
<i>Andrena fragilis</i> (Smith, 1853)

Table 2.1 (cont.)
<i>Andrena frigida</i> (Smith, 1853)^
<i>Andrena geranii</i> (Robertson, 1891)
<i>Andrena haynesi</i> (Viereck & Cockerell, 1914)^
<i>Andrena helianthi</i> (Robertson, 1891)
<i>Andrena heraclei</i> (Robertson, 1897)
<i>Andrena hippotes</i> (Robertson, 1895)
<i>Andrena hirticincta</i> (Provancher, 1888)
<i>Andrena ilicis</i> (Mitchell, 1960)
<i>Andrena illini</i> (Bouseman & LaBerge, 1979)
<i>Andrena illinoensis</i> (Robertson, 1891)
<i>Andrena imitatrix</i> (Cresson, 1872)
<i>Andrena integra</i> (Smith, 1853)
<i>Andrena ishii</i> (Ribble, 1968)
<i>Andrena krigiana</i> (Robertson, 1901)
<i>Andrena lauracea</i> (Robertson, 1897)
<i>Andrena lupinorum</i> (Cockerell, 1906)^
<i>Andrena macoupinensis</i> (Robertson, 1900)
<i>Andrena mandibularis</i> (Robertson, 1892)
<i>Andrena mariae</i> (Robertson, 1891)
<i>Andrena melanothroa</i> (Cockerell, 1898)
<i>Andrena mendica</i> (Mitchell, 1960)^
<i>Andrena milwaukeeensis</i> (Graenicher, 1903)
<i>Andrena miranda</i> (Smith, 1879)
<i>Andrena miserabilis</i> (Cresson, 1872)
<i>Andrena morrisonella</i> (Viereck, 1917)
<i>Andrena nasonii</i> (Robertson, 1895)
<i>Andrena neonana</i> (Viereck, 1917)
<i>Andrena nida</i> (Mitchell, 1960)
<i>Andrena nigerrima</i> (Casad, 1896)
<i>Andrena nigrae</i> (Robertson, 1905)
<i>Andrena nivalis</i> (Smith, 1853)
<i>Andrena nothoscordi</i> (Robertson, 1897)
<i>Andrena nubecula</i> (Smith, 1853)
<i>Andrena nuda</i> (Robertson, 1891)
<i>Andrena pallidiscopa</i> (Viereck, 1904)
<i>Andrena perezana</i> (Viereck & Cockerell, 1914)
<i>Andrena perplexa</i> (Smith, 1853)
<i>Andrena personata</i> (Robertson, 1897)
<i>Andrena phaceliae</i> (Mitchell, 1960)
<i>Andrena placata</i> (Mitchell, 1960)
<i>Andrena platyparia</i> (Robertson, 1895)

Table 2.1 (cont.)
<i>Andrena polemonii</i> (Robertson, 1891)
<i>Andrena pruni</i> (Robertson, 1891)
<i>Andrena quintilis</i> (Robertson, 1898)
<i>Andrena regularis</i> (Malloch, 1917)^
<i>Andrena robertsonii</i> (Dalla Torre, 1896)
<i>Andrena rudbeckiae</i> (Robertson, 1891)
<i>Andrena rufosignata</i> (Cockerell, 1902)^
<i>Andrena rugosa</i> (Robertson, 1891)
<i>Andrena salicina</i> (Morawitz, 1877)
<i>Andrena salictaria</i> (Robertson, 1905)
<i>Andrena sayi</i> (Robertson, 1891)
<i>Andrena sigmundi</i> (Cockerell, 1902)
<i>Andrena simplex</i> (Smith, 1853)
<i>Andrena spiraean</i> (Robertson, 1895)
<i>Andrena thaspiae</i> (Graenicher, 1903)^
<i>Andrena tridens</i> (Robertson, 1902)
<i>Andrena unicostata</i> (LaBerge, 1971)
<i>Andrena vicina</i> (Smith, 1853)
<i>Andrena violae</i> (Robertson, 1891)
<i>Andrena virginiana</i> (Mitchell, 1960)
<i>Andrena wellesleyana</i> (Robertson, 1897)
<i>Andrena wheeleri</i> (Graenicher, 1904)^
<i>Andrena wilkella</i> (Kirby, 1802)
<i>Andrena wilmattae</i> (Cockerell, 1906)
<i>Andrena ziziae</i> (Robertson, 1891)
<i>Andrena ziziaeformis</i> (Cockerell, 1906)
<i>Anthemurgus passiflorae</i> (Robertson, 1902)
<i>Calliopsis andreniformis</i> (Smith, 1853)
<i>Calliopsis coloradensis</i> (Cresson, 1878)
<i>Calliopsis nebraskensis</i> (Crawford, 1902)
<i>Panurginus cressoniellus</i> (Cockerell, 1898)^
<i>Panurginus potentillae</i> (Crawford, 1916)
<i>Perdita albipennis</i> (Cresson, 1868)
<i>Perdita bequaerti</i> (Viereck, 1917)
<i>Perdita boltoniae</i> (Robertson, 1902)
<i>Perdita gerhardi</i> (Viereck, 1904)
<i>Perdita halictoides</i> (Smith, 1853)
<i>Perdita maculigera</i> (Cockerell, 1896)
<i>Perdita octomaculata</i> (Say, 1824)
<i>Perdita swenki</i> (Crawford, 1915)^
<i>Protandrena mexicanorum</i> (Cockerell, 1896)

Table 2.1 (cont.)
<i>Pseudopanurgus aestivalis</i> (Provancher, 1882)
<i>Pseudopanurgus albitarsis</i> (Cresson, 1872)
<i>Pseudopanurgus andrenoides</i> (Smith, 1853)
<i>Pseudopanurgus compositarum</i> (Robertson, 1893)
<i>Pseudopanurgus illinoiensis</i> (Cresson, 1878)
<i>Pseudopanurgus labrosiformis</i> (Robertson, 1898)
<i>Pseudopanurgus labrosus</i> (Robertson, 1895)
<i>Pseudopanurgus ornatipes</i> (Cresson, 1872)
<i>Pseudopanurgus parvus</i> (Robertson, 1892)
<i>Pseudopanurgus pauper</i> (Cresson, 1878)
<i>Pseudopanurgus rudbeckiae</i> (Robertson, 1895)
<i>Pseudopanurgus rugosus</i> (Robertson, 1895)
<i>Pseudopanurgus simulans</i> (Swenk & Cockerell, 1907)^
<i>Pseudopanurgus solidaginis</i> (Robertson, 1893)
Apidae
<i>Anthophora abrupta</i> (Say, 1837)
<i>Anthophora bomboides</i> (Kirby, 1837)^
<i>Anthophora terminalis</i> (Cresson, 1869)
<i>Anthophora ursina</i> (Cresson, 1869)
<i>Anthophora walshii</i> (Cresson, 1869)
<i>Apis mellifera</i> (Linnaeus, 1758)
<i>Bombus affinis</i> (Cresson, 1863)
<i>Bombus auricomus</i> (Robertson, 1903)
<i>Bombus bimaculatus</i> (Cresson, 1863)
<i>Bombus borealis</i> (Kirby, 1837)
<i>Bombus citrinus</i> (Smith, 1854)
<i>Bombus fervidus</i> (Fabricius, 1798)
<i>Bombus fraternus</i> (Smith, 1854)
<i>Bombus frigidus</i> (Smith, 1854)
<i>Bombus griseocollis</i> (DeGeer, 1773)
<i>Bombus hypocrita</i> (Perez, 1905)^
<i>Bombus impatiens</i> (Cresson, 1863)
<i>Bombus lapponicus</i> (Fabricius, 1793)^
<i>Bombus morrisoni</i> (Cresson, 1878)
<i>Bombus pensylvanicus</i> (DeGeer, 1773)
<i>Bombus perplexus</i> (Cresson, 1863)
<i>Bombus rufocinctus</i> (Cresson, 1863)
<i>Bombus ternarius</i> (Say, 1837)
<i>Bombus terricola</i> (Kirby, 1837)
<i>Bombus vagans</i> (Smith, 1854)
<i>Bombus variabilis</i> (Cresson, 1872)

Table 2.1 (cont.)
<i>Cemolobus ipomoeae</i> (Robertson, 1891)
<i>Ceratina calcarata</i> (Robertson, 1900)
<i>Ceratina dupla</i> (Say, 1837)
<i>Ceratina strenua</i> (Smith, 1879)
<i>Epeolus autumnalis</i> (Robertson, 1902)
<i>Epeolus bifasciatus</i> (Cresson, 1864)
<i>Epeolus interruptus</i> (Robertson, 1900)
<i>Epeolus lectoides</i> (Robertson, 1901)
<i>Epeolus minimus</i> (Robertson, 1902)^
<i>Epeolus pusillus</i> (Cresson, 1864)
<i>Epeolus scutellaris</i> (Say, 1824)^
<i>Eucera atriventris</i> (Smith, 1854)
<i>Eucera belfragii</i> (Cresson, 1872)
<i>Eucera hamata</i> (Bradley, 1942)
<i>Eucera illinoensis</i> (Robertson, 1902)^
<i>Eucera rosae</i> (Robertson, 1900)
<i>Eucera speciosa</i> (Cresson, 1878)
<i>Exomalopsis similis</i> (Cresson, 1865)^
<i>Florilegus condignus</i> (Cresson, 1878)
<i>Habropoda laboriosa</i> (Fabricius, 1804)
<i>Holcopasites calliopsidis</i> (Linsley, 1943)
<i>Holcopasites heliopsis</i> (Robertson, 1897)^
<i>Holcopasites illinoiensis</i> (Robertson, 1891)
<i>Melecta pacifica</i> (Cresson, 1878)
<i>Melissodes agilis</i> (Cresson, 1878)
<i>Melissodes bidentis</i> (Cockerell, 1914)^
<i>Melissodes bimaculata</i> (Lepeletier, 1825)
<i>Melissodes boltoniae</i> (Robertson, 1905)
<i>Melissodes coloradensis</i> (Cresson, 1878)
<i>Melissodes communis</i> (Cresson, 1878)
<i>Melissodes comptoides</i> (Robertson, 1898)
<i>Melissodes coreopsis</i> (Robertson, 1905)
<i>Melissodes denticulata</i> (Smith, 1854)
<i>Melissodes dentiventris</i> (Smith, 1854)
<i>Melissodes desponsa</i> (Smith, 1854)
<i>Melissodes druriellus</i> (Kirby, 1802)
<i>Melissodes fimbriata</i> (Cresson, 1878)^
<i>Melissodes fumosa</i> (LaBerge, 1961)
<i>Melissodes gelida</i> (LaBerge, 1961)
<i>Melissodes manipularis</i> (Smith, 1854)^
<i>Melissodes menuachus</i> (Cresson, 1868)^

Table 2.1 (cont.)
<i>Melissodes nivea</i> (Robertson, 1895)
<i>Melissodes subillata</i> (LaBerge, 1961)
<i>Melissodes tepaneca</i> (Cresson, 1878)
<i>Melissodes tinctoria</i> (LaBerge, 1961)^
<i>Melissodes trinodis</i> (Robertson, 1901)
<i>Melissodes tristis</i> (Cockerell, 1894)^
<i>Melissodes vernoniae</i> (Robertson, 1902)
<i>Melissodes wheeleri</i> (Cockerell, 1906)
<i>Melitoma taurea</i> (Say, 1837)
<i>Nomada affabilis</i> (Cresson, 1878)
<i>Nomada articulata</i> (Smith, 1854)
<i>Nomada banksi</i> (Cockerell, 1907)
<i>Nomada bella</i> (Cresson, 1863)
<i>Nomada cressonii</i> (Robertson, 1893)
<i>Nomada cuneata</i> (Robertson, 1903)
<i>Nomada dentariae</i> (Robertson, 1903)
<i>Nomada denticulata</i> (Robertson, 1902)
<i>Nomada erigeronis</i> (Robertson, 1897)
<i>Nomada fervida</i> (Smith, 1854)
<i>Nomada hydrophylli</i> (Swenk, 1915)
<i>Nomada illinoensis</i> (Robertson, 1900)
<i>Nomada imbricata</i> (Smith, 1854)^
<i>Nomada integerrima</i> (Dalla Torre, 1896)
<i>Nomada luteola</i> (Olivier, 1811)
<i>Nomada luteoloides</i> (Robertson, 1895)
<i>Nomada maculata</i> (Cresson, 1863)^
<i>Nomada obliterated</i> (Cresson, 1863)
<i>Nomada ovata</i> (Robertson, 1903)
<i>Nomada parva</i> (Robertson, 1900)
<i>Nomada placida</i> (Cresson, 1863)
<i>Nomada pygmaea</i> (Cresson, 1863)^
<i>Nomada rubicunda</i> (Olivier, 1811)
<i>Nomada salicis</i> (Robertson, 1900)^
<i>Nomada sayi</i> (Robertson, 1893)
<i>Nomada sulphurata</i> (Smith, 1854)^
<i>Nomada superba</i> (Cresson, 1863)
<i>Nomada vegana</i> (Cockerell, 1903)
<i>Peponapis pruinosa</i> (Say, 1837)
<i>Ptilothrix bombiformis</i> (Cresson, 1878)
<i>Svastra atripes</i> (Cresson, 1872)
<i>Svastra compta</i> (Cresson, 1878)

Table 2.1 (cont.)
<i>Svastra obliqua</i> (Say, 1873)
<i>Svastra petulca</i> (Cresson, 1878)
<i>Triepeolus atripes</i> (Mitchell, 1962)
<i>Triepeolus concavus</i> (Cresson, 1878)
<i>Triepeolus cressonii</i> (Robertson, 1897)
<i>Triepeolus distinctus</i> (Cresson, 1878)
<i>Triepeolus donatus</i> (Smith, 1854)
<i>Triepeolus helianthi</i> (Robertson, 1897)
<i>Triepeolus lunatus</i> (Say, 1824)
<i>Triepeolus micropygius</i> (Robertson, 1903)^
<i>Triepeolus pectoralis</i> (Robertson, 1897)
<i>Triepeolus quadrifasciatus</i> (Say, 1823)
<i>Triepeolus remigatus</i> (Fabricius, 1804)
<i>Triepeolus simplex</i> (Robertson, 1903)
<i>Xenoglossa strenua</i> (Cresson, 1878)
<i>Xeromelecta interrupta</i> (Cresson, 1872)
<i>Xylocopa micans</i> (Lepelletier, 1841)^
<i>Xylocopa virginica</i> (Linnaeus, 1771)
Colletidae
<i>Colletes aberrans</i> (Cockerell, 1897)
<i>Colletes aestivalis</i> (Patton, 1879)
<i>Colletes albescens</i> (Cresson, 1868)^
<i>Colletes americanus</i> (Cresson, 1868)
<i>Colletes brevicornis</i> (Robertson, 1897)
<i>Colletes ciliatus</i> ^ (Patton, 1879)
<i>Colletes compactus</i> (Cresson, 1868)
<i>Colletes eulophi</i> (Robertson, 1891)
<i>Colletes inaequalis</i> (Say, 1837)
<i>Colletes kincaidii</i> (Cockerell, 1898)
<i>Colletes latitarsis</i> (Robertson, 1891)
<i>Colletes mandibularis</i> (Smith, 1853)
<i>Colletes nudus</i> (Robertson, 1898)
<i>Colletes productus</i> (Robertson, 1891)^
<i>Colletes robertsonii</i> (Dalla Torre, 1896)
<i>Colletes simulans</i> (Cresson, 1868)
<i>Colletes solidaginis</i> (Swenk, 1906)
<i>Colletes validus</i> (Cresson, 1868)
<i>Colletes willistoni</i> (Robertson, 1891)
<i>Hylaeus affinis</i> (Smith, 1853)
<i>Hylaeus leptocephalus</i> (Morawitz, 1871)
<i>Hylaeus floridanus</i> (Robertson, 1893)

Table 2.1 (cont.)
<i>Hylaeus illinoisensis</i> (Robertson, 1896)
<i>Hylaeus mesillae</i> (Cockerell, 1896)
<i>Hylaeus modestus</i> (Say, 1837)
<i>Hylaeus nelumbonis</i> (Robertson, 1890)
<i>Hylaeus rudbeckiae</i> (Cockerell & Casad, 1895)
<i>Hylaeus saniculae</i> (Robertson, 1896)
<i>Hylaeus sparsus</i> (Cresson, 1869)
<i>Hylaeus verticalis</i> (Cresson, 1869)
Halictidae
<i>Agapostemon leunculus</i> (Vachal, 1903)
<i>Agapostemon obliquus</i> (Provancher, 1888)^
<i>Agapostemon sericeus</i> (Forster, 1771)
<i>Agapostemon splendens</i> (Lepeletier, 1841)
<i>Agapostemon texanus</i> (Cresson, 1872)
<i>Agapostemon virescens</i> (Fabricius, 1775)
<i>Augochlora pura</i> (Say, 1837)
<i>Augochlorella aurata</i> (Smith, 1853)
<i>Augochlorella persimilis</i> (Viereck, 1910)
<i>Augochloropsis metallica</i> (Fabricius, 1793)
<i>Augochloropsis sumptuosa</i> (Smith, 1853)
<i>Dieunomia heteropoda</i> (Say, 1824)
<i>Dieunomia triangulifera</i> (Vachal, 1897)
<i>Dufourea marginata</i> (Cresson, 1878)^
<i>Dufourea monardae</i> (Viereck, 1924)
<i>Dufourea novaeangliae</i> (Robertson, 1897)
<i>Halictus confusus</i> (Smith, 1853)
<i>Halictus ligatus</i> (Say, 1837)
<i>Halictus maculatus</i> (Smith, 1848)
<i>Halictus parallelus</i> (Say, 1837)
<i>Halictus rubicundus</i> (Christ, 1791)
<i>Lasioglossum abanci</i> (Crawford, 1932)
<i>Lasioglossum achilleae</i> (Mitchell, 1960)^
<i>Lasioglossum admirandum</i> (Sandhouse, 1924)
<i>Lasioglossum albipenne</i> (Robertson, 1890)
<i>Lasioglossum anomalum</i> (Robertson, 1892)
<i>Lasioglossum apocyni</i> (Mitchell, 1960)
<i>Lasioglossum apokense</i> (Robertson, 1892)
<i>Lasioglossum athabascense</i> (Sandhouse, 1933)
<i>Lasioglossum bruneri</i> (Crawford, 1902)
<i>Lasioglossum cinctipes</i> (Provancher, 1888)^
<i>Lasioglossum coeruleum</i> (Robertson, 1893)

Table 2.1 (cont.)
<i>Lasioglossum connexum</i> (Cresson, 1872)
<i>Lasioglossum coreopsis</i> (Robertson, 1902)
<i>Lasioglossum coriaceum</i> (Smith, 1853)
<i>Lasioglossum cressonii</i> (Robertson, 1890)
<i>Lasioglossum discum</i> (Smith, 1853)
<i>Lasioglossum disparile</i> (Cresson, 1872)
<i>Lasioglossum divergens</i> (Lovell, 1905)
<i>Lasioglossum fattigi</i> (Mitchell, 1960)
<i>Lasioglossum flaveriae</i> (Mitchell, 1960)
<i>Lasioglossum forbesii</i> (Robertson, 1890)
<i>Lasioglossum foveolatum</i> (Robertson, 1902)
<i>Lasioglossum foxii</i> (Robertson, 1895)
<i>Lasioglossum fuscipenne</i> (Smith, 1853)
<i>Lasioglossum halophitum</i> (Graenicher, 1927)^
<i>Lasioglossum hitchensi</i> (Gibbs, 2012)
<i>Lasioglossum illinoense</i> (Robertson, 1892)
<i>Lasioglossum imitatum</i> (Smith, 1853)
<i>Lasioglossum laevissimum</i> (Smith, 1853)
<i>Lasioglossum lineatulum</i> (Crawford, 1906)
<i>Lasioglossum macoupinense</i> (Robertson, 1895)
<i>Lasioglossum nelumbonis</i> (Robertson, 1890)
<i>Lasioglossum nigroviride</i> (Graenicher, 1911)
<i>Lasioglossum novascotiae</i> (Mitchell, 1960)
<i>Lasioglossum nymphaearum</i> (Robertson, 1895)
<i>Lasioglossum nymphale</i> (Smith, 1853)
<i>Lasioglossum oblongum</i> (Lovell, 1905)
<i>Lasioglossum obscurum</i> (Robertson, 1892)
<i>Lasioglossum paraforbesii</i> (McGinley, 1986)
<i>Lasioglossum pectorale</i> (Smith, 1853)
<i>Lasioglossum perpunctatum</i> (Ellis, 1913)
<i>Lasioglossum pictum</i> (Crawford, 1902)
<i>Lasioglossum pilosum</i> (Smith, 1853)
<i>Lasioglossum platyparium</i> (Robertson, 1895)
<i>Lasioglossum pruinatum</i> (Robertson, 1892)
<i>Lasioglossum semicaeruleum</i> (Cockerell, 1895)
<i>Lasioglossum simplex</i> (Robertson, 1901)^
<i>Lasioglossum sopinci</i> (Crawford, 1932)
<i>Lasioglossum subversans</i> (Mitchell, 1960)
<i>Lasioglossum tegulare</i> (Robertson, 1890)
<i>Lasioglossum testaceum</i> (Robertson, 1897)
<i>Lasioglossum texanum</i> (Cresson, 1872)

Table 2.1 (cont.)
<i>Lasioglossum truncatum</i> (Robertson, 1901)
<i>Lasioglossum versans</i> (Lovell, 1905)
<i>Lasioglossum versatum</i> (Robertson, 1902)
<i>Lasioglossum vierecki</i> (Crawford, 1904)
<i>Lasioglossum viridatum</i> (Lovell, 1905)
<i>Lasioglossum weemsi</i> (Mitchell, 1960)^
<i>Lasioglossum wheeleri</i> (Mitchell, 1960)^
<i>Lasioglossum zephyrum</i> (Smith, 1853)
<i>Lasioglossum zonulum</i> (Smith, 1848)
<i>Nomia nortoni</i> (Cresson, 1868)
<i>Sphecodes antennariae</i> (Robertson, 1891)
<i>Sphecodes aroniae</i> (Mitchell, 1960)
<i>Sphecodes brachycephalus</i> (Mitchell, 1956)^
<i>Sphecodes clematidis</i> (Robertson, 1897)
<i>Sphecodes confertus</i> (Say, 1837)
<i>Sphecodes cressonii</i> (Robertson, 1903)
<i>Sphecodes dichrous</i> (Smith, 1853)
<i>Sphecodes galerus</i> (Lovell & Cockerell, 1907)
<i>Sphecodes heraclei</i> (Robertson, 1897)
<i>Sphecodes illinoensis</i> (Robertson, 1903)
<i>Sphecodes levis</i> (Lovell & Cockerell, 1907)
<i>Sphecodes mandibularis</i> (Cresson, 1872)
<i>Sphecodes minor</i> (Robertson, 1898)^
<i>Sphecodes persimilis</i> (Lovell & Cockerell, 1907)
<i>Sphecodes pimpinellae</i> (Robertson, 1900)
<i>Sphecodes prosphorus</i> (Lovell & Cockerell, 1907)^
<i>Sphecodes pycnanthemii</i> (Robertson, 1897)
<i>Sphecodes ranunculi</i> (Robertson, 1897)
<i>Sphecodes smilacinae</i> (Robertson, 1897)
<i>Sphecodes stygius</i> (Robertson, 1893)
Megachilidae
<i>Anthidiellum notatum</i> (Latreille, 1809)
<i>Anthidium maculifrons</i> (Smith, 1854)
<i>Anthidium psoraleae</i> (Robertson, 1902)
<i>Ashmeadiella bucconis</i> (Say, 1837)
<i>Chelostoma philadelphi</i> (Robertson, 1891)
<i>Coelioxys alternata</i> (Say, 1837)
<i>Coelioxys germana</i> (Cresson, 1878)
<i>Coelioxys hunteri</i> (Crawford, 1914)
<i>Coelioxys modesta</i> (Smith, 1854)
<i>Coelioxys octodentata</i> (Say, 1824)

Table 2.1 (cont.)
<i>Coelioxys rufitarsis</i> (Smith, 1854)
<i>Coelioxys sayi</i> (Robertson, 1897)
<i>Heriades carinata</i> (Cresson, 1864)
<i>Heriades leavitti</i> (Crawford, 1913)
<i>Heriades variolosa</i> (Cresson, 1872)
<i>Hoplitis pilosifrons</i> (Cresson, 1864)
<i>Hoplitis producta</i> (Cresson, 1964)
<i>Hoplitis spoliata</i> (Provancher, 1888)
<i>Hoplitis truncata</i> (Cresson, 1878)
<i>Megachile addenda</i> (Cresson, 1878)
<i>Megachile brevis</i> (Say, 1837)
<i>Megachile campanulae</i> (Robertson, 1903)
<i>Megachile centuncularis</i> (Linnaeus, 1758)
<i>Megachile concinna</i> (Smith, 1879)
<i>Megachile fortis</i> (Cresson, 1872)
<i>Megachile gemula</i> (Cresson, 1878)
<i>Megachile georgica</i> (Cresson, 1878) [^]
<i>Megachile inimica</i> (Cresson, 1872)
<i>Megachile integra</i> (Cresson, 1878)
<i>Megachile latimanus</i> (Say, 1823)
<i>Megachile mendica</i> (Cresson, 1878)
<i>Megachile montivaga</i> (Cresson, 1878)
<i>Megachile parallela</i> (Smith, 1853)
<i>Megachile petulans</i> (Cresson, 1878)
<i>Megachile policaris</i> (Say, 1831)
<i>Megachile pugnata</i> (Say, 1837)
<i>Megachile relativa</i> (Cresson, 1878)
<i>Megachile rotundata</i> (Fabricius, 1793)
<i>Megachile rugifrons</i> (Smith, 1854)
<i>Megachile texana</i> (Cresson, 1878)
<i>Osmia albiventris</i> (Cresson, 1864)
<i>Osmia bucephala</i> (Cresson, 1864)
<i>Osmia caeruleascens</i> (Linnaeus, 1758) [^]
<i>Osmia collinsiae</i> (Robertson, 1905)
<i>Osmia conjuncta</i> (Cresson, 1864)
<i>Osmia cordata</i> (Robertson, 1902)
<i>Osmia distincta</i> (Cresson, 1864)
<i>Osmia georgica</i> (Cresson, 1878)
<i>Osmia illinoensis</i> (Robertson, 1897) [^]
<i>Osmia lignaria</i> (Say, 1837)
<i>Osmia pumila</i> (Cresson, 1864)

Table 2.1 (cont.)
<i>Osmia simillima</i> (Smith, 1853)
<i>Stelis labiata</i> (Provancher, 1888)
<i>Stelis lateralis</i> (Cresson, 1864)^
<i>Stelis louisae</i> (Cockerell, 1911)^
<i>Stelis permaculata</i> (Cockerell, 1898)
Melittidae
<i>Hesperapis carinata</i> (Stevens, 1919)^
<i>Macropis ciliata</i> (Patton, 1880)
<i>Macropis nuda</i> (Provancher, 1882)
<i>Macropis patellata</i> (Patton, 1880)^
<i>Macropis steironematis</i> (Robertson, 1891)

Table 2.2: List of bee species from the recent collecting effort and INHS for Effingham, Fayette, Jasper, and Marion Counties of Illinois. Asterisks (*) denote potential declining or not detected species in the recent collecting effort; carrot signs (^) denote potential new county records; bolded plus signs (+) denote potential new state records, which have been marked for verification.

Andrenidae
<i>Andrena accepta</i> (Viereck, 1916)*
<i>Andrena barbara</i> (Bouseman & LaBerge, 1979)*
<i>Andrena brevipalpis</i> (Cockerell, 1903)*
<i>Andrena carlini</i> (Cockerell, 1901)*
<i>Andrena confederata</i> (Viereck, 1917)*
<i>Andrena crataegi</i> (Robertson, 1893)*
<i>Andrena cressonii</i> (Robertson, 1891)
<i>Andrena forbesii</i> (Robertson, 1891)*
<i>Andrena ilicis</i> (Mitchell, 1960)
<i>Andrena imitatrix</i> (Cresson, 1872)
<i>Andrena mariae</i> (Robertson, 1891)*
<i>Andrena miserabilis</i> (Cresson, 1872)*
<i>Andrena nuda</i> (Robertson, 1891)*
<i>Andrena perplexa</i> (Smith, 1853)
<i>Andrena personata</i> (Robertson, 1897)*
<i>Andrena quintilis</i> (Robertson, 1898)*
<i>Andrena rudbeckiae</i> (Robertson, 1891)
<i>Andrena sayi</i> (Robertson, 1891)*
<i>Andrena simplex</i> (Smith, 1853)^
<i>Andrena violae</i> (Robertson, 1891)^
<i>Andrena wilkella</i> (Kirby, 1802)^
<i>Andrena ziziae</i> (Robertson, 1891)*
<i>Calliopsis andreniformis</i> (Smith, 1853)
<i>Calliopsis nebraskensis</i> (Crawford, 1902)*
<i>Pseudopanurgus ornatipes</i> (Cresson, 1872)*
Apidae
<i>Anthophora abrupta</i> (Say, 1837)^
<i>Anthophora terminalis</i> (Cresson, 1869)^
<i>Anthophora walshii</i> (Cresson, 1869)^
<i>Apis mellifera</i> (Linnaeus, 1758)^
<i>Bombus auricomus</i> (Robertson, 1903)^
<i>Bombus bimaculatus</i> (Cresson, 1863)
<i>Bombus fervidus</i> (Fabricius, 1798)^
<i>Bombus fraternus</i> (Smith, 1854)^
<i>Bombus griseocollis</i> (DeGeer, 1773)

Table 2.2 (cont.)
<i>Bombus impatiens</i> (Cresson, 1863)
<i>Bombus pensylvanicus</i> (DeGeer, 1773)
<i>Bombus vagans</i> (Smith, 1854)^
<i>Cemolobus ipomoeae</i> (Robertson, 1891)
<i>Ceratina calcarata</i> (Robertson, 1900)^
<i>Ceratina dupla</i> (Say, 1837)
<i>Ceratina floridana</i> (Mitchell, 1962)+
<i>Ceratina mikmaqi</i> (Rehan & Sheffield, 2011)+
<i>Ceratina strenua</i> (Smith, 1879)^
<i>Diadasia enavata</i> (Cresson, 1872)+
<i>Eucera hamata</i> (Bradley, 1942)
<i>Eucera rosae</i> (Robertson, 1900)^
<i>Florilegus condignus</i> (Cresson, 1878)*
<i>Holcopasites calliopsidis</i> (Linsley, 1943)*
<i>Melissodes agilis</i> (Cresson, 1878)
<i>Melissodes bidentis</i> (Cockerell, 1914)^
<i>Melissodes bimaculata</i> (Lepelletier, 1825)
<i>Melissodes boltoniae</i> (Robertson, 1905)
<i>Melissodes coloradensis</i> (Cresson, 1878)*
<i>Melissodes communis</i> (Cresson, 1878)^
<i>Melissodes comptoides</i> (Robertson, 1898)
<i>Melissodes coreopsis</i> (Robertson, 1905)^
<i>Melissodes denticulata</i> (Smith, 1854)
<i>Melissodes dentiventris</i> (Smith, 1854)*
<i>Melissodes desponsa</i> (Smith, 1854)
<i>Melissodes druriellus</i> (Kirby, 1802)^
<i>Melissodes tincta</i> (LaBerge, 1961)^
<i>Melissodes trinodis</i> (Robertson, 1901)
<i>Melissodes vernoniae</i> (Robertson, 1902)
<i>Melissodes wheeleri</i> (Cockerell, 1906)
<i>Melitoma taurea</i> (Say, 1837)^
<i>Nomada articulata</i> (Smith, 1854)*
<i>Nomada cressonii</i> (Robertson, 1893)^
<i>Peponapis pruinosa</i> (Say, 1837)^
<i>Ptilothrix bombiformis</i> (Cresson, 1878)^
<i>Svastra atripes</i> (Cresson, 1872)^
<i>Svastra obliqua</i> (Say, 1873)
<i>Triepeolus concavus</i> (Cresson, 1878)
<i>Triepeolus cressonii</i> (Robertson, 1897)^
<i>Triepeolus donatus</i> (Smith, 1854)^
<i>Triepeolus helianthi</i> (Robertson, 1897)*

Table 2.2 (cont.)
<i>Triepeolus lunatus</i> (Say, 1824)
<i>Triepeolus simplex</i> (Robertson, 1903)
<i>Xenoglossa strenua</i> Cresson, 1878)^
<i>Xylocopa virginica</i> (Linnaeus, 1771)
Colletidae
<i>Colletes americanus</i> (Cresson, 1868)*
<i>Colletes latitarsis</i> (Robertson, 1891)
<i>Colletes simulans</i> (Cresson, 1868)*
<i>Colletes willistoni</i> (Robertson, 1891)*
<i>Hylaeus affinis</i> (Smith, 1853)
<i>Hylaeus illinoisensis</i> (Robertson, 1896)^
<i>Hylaeus mesillae</i> (Cockerell, 1896)
<i>Hylaeus modestus</i> (Say, 1837)^
Halictidae
<i>Agapostemon sericeus</i> (Forster, 1771)^
<i>Agapostemon texanus</i> (Cresson, 1872)^
<i>Agapostemon virescens</i> (Fabricius, 1775)
<i>Augochlora pura</i> (Say, 1837)
<i>Augochlorella aurata</i> (Smith, 1853)
<i>Augochlorella persimilis</i> (Viereck, 1910)
<i>Augochloropsis metallica</i> (Fabricius, 1793)
<i>Augochloropsis sumptuosa</i> (Smith, 1853)^
<i>Dieunomia heteropoda</i> (Say, 1824)*
<i>Halictus confusus</i> (Smith, 1853)
<i>Halictus ligatus</i> (Say, 1837)
<i>Halictus parallelus</i> (Say, 1837)
<i>Halictus rubicundus</i> (Christ, 1791)
<i>Lasioglossum acuminatum</i> (McGinley, 1986)+
<i>Lasioglossum admirandum</i> (Sandhouse, 1924)
<i>Lasioglossum albipenne</i> (Robertson, 1890)
<i>Lasioglossum bruneri</i> (Crawford, 1902)
<i>Lasioglossum callidum</i> (Sandhouse, 1924)+
<i>Lasioglossum coeruleum</i> (Robertson, 1893)
<i>Lasioglossum coreopsis</i> (Robertson, 1902)^
<i>Lasioglossum coriaceum</i> (Smith, 1853)^
<i>Lasioglossum cressonii</i> (Robertson, 1890)
<i>Lasioglossum hitchensi</i> (Gibbs, 2012)^
<i>Lasioglossum imitatum</i> (Smith, 1853)^
<i>Lasioglossum lineatulum</i> (Crawford, 1906)^
<i>Lasioglossum nelumbonis</i> (Robertson, 1890)^
<i>Lasioglossum pectorale</i> (Smith, 1853)^

Table 2.2 (cont.)
<i>Lasioglossum perpunctatum</i> (Ellis, 1913)*
<i>Lasioglossum pilosum</i> (Smith, 1853)*
<i>Lasioglossum platyparium</i> (Robertson, 1895)^
<i>Lasioglossum pruinatum</i> (Robertson, 1892)^
<i>Lasioglossum simplex</i> (Robertson, 1901)^
<i>Lasioglossum smilacinae</i> (Robertson, 1897)+
<i>Lasioglossum tegulare</i> (Robertson, 1890)
<i>Lasioglossum trigeminum</i> (Gibbs, 2011)+
<i>Lasioglossum truncatum</i> (Robertson, 1901)^
<i>Lasioglossum versatum</i> (Robertson, 1902)
<i>Lasioglossum viridatum</i> (Lovell, 1905)*
<i>Lasioglossum weemsi</i> (Mitchell, 1960)^
<i>Lasioglossum zephyrum</i> (Smith, 1853)
<i>Nomia nortoni</i> (Cresson, 1868)*
<i>Sphecodes heraclei</i> (Robertson, 1897)*
<i>Sphecodes pimpinellae</i> (Robertson, 1900)^
<i>Sphecodes prosporus</i> (Lovell & Cockerell, 1907)*
Megachilidae
<i>Ashmeadiella buconis</i> (Say, 1837)^
<i>Coelioxys octodentata</i> (Say, 1824)
<i>Heriades leavitti</i> (Crawford, 1913)^
<i>Heriades variolosa</i> (Cresson, 1872)^
<i>Hoplitis pilosifrons</i> (Cresson, 1864)
<i>Hoplitis producta</i> (Cresson, 1964)*
<i>Hoplitis truncata</i> (Cresson, 1878)^
<i>Megachile albitarsis</i> (Cresson, 1872)+
<i>Megachile brevis</i> (Say, 1837)
<i>Megachile centuncularis</i> (Linnaeus, 1758)^
<i>Megachile frugalis</i> (Cresson, 1872)+
<i>Megachile inimica</i> (Cresson, 1872)
<i>Megachile mendica</i> (Cresson, 1878)
<i>Megachile montivaga</i> (Cresson, 1878)^
<i>Megachile parallela</i> (Smith, 1853)^
<i>Megachile petulans</i> (Cresson, 1878)
<i>Megachile polycaris</i> (Say, 1831)*
<i>Megachile pugnata</i> (Say, 1837)^
<i>Osmia georgica</i> (Cresson, 1878)^
<i>Osmia lignaria</i> (Say, 1837)*
<i>Stelis lateralis</i> (Cresson, 1864)^

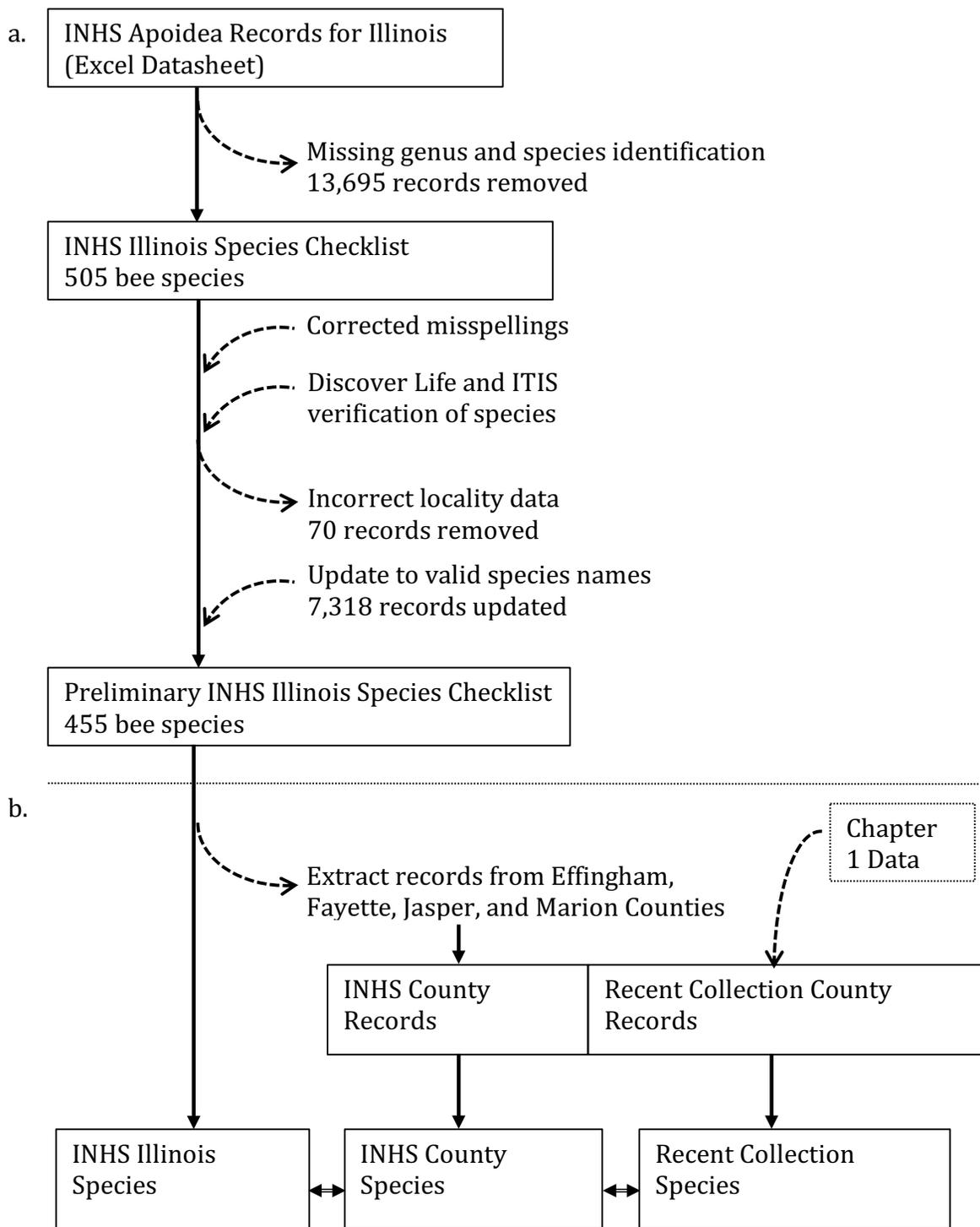


Figure 2.1: Diagram of the process for a) checking and updating the INHS bee database, and b) comparing species between the full INHS bee species checklist, INHS species recorded in the four counties, and the species from the recent collecting effort.

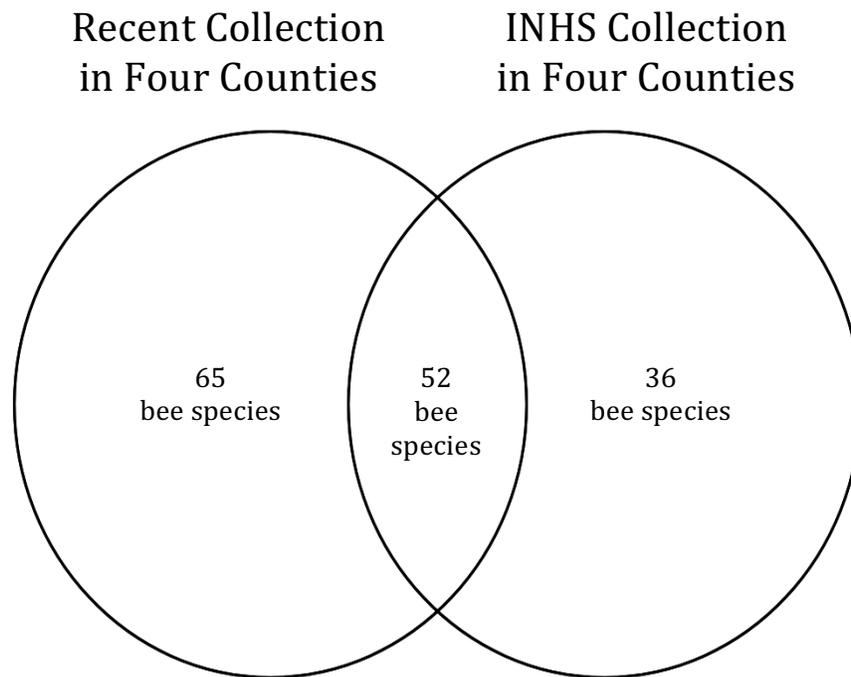


Figure 2.2: Venn diagram depicting shared and unique bee species between the recent collection described in Chapter 1 and the records housed at INHS for Effingham, Fayette, Jasper, and Marion Counties of Illinois. Sixty-five species were unique to the recent 2016-2017 collecting effort, 36 were unique to the INHS collections, and 52 were recorded in both.

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APPENDIX A: CHAPTER 1 SUPPLEMENTARY TABLE AND REFERENCES

Table A.1: Species of bee recorded during the 2016-2017 collecting event. Nest Guild: A = above-ground nesting; B = below-ground nesting; numbers indicate the reference; asterisk (*) = presumed nesting strategy due to lack of specific literature pertaining to the species. Trap Method: A = actively netted off of flowers, V = captured in a blue vane traps, P = captured in a pan trap. Burn Treatment: DS = captured in the dormant season treatment, GS = captured in the growing season treatment, UB = captured in the unburned treatment. Total abundances of each species are given.

Species of Bee	Nest Guild	Trap Method	Burn Treatment	Total Abundance
Andrenidae				
<i>Andrena cressonii</i>	B ⁵⁰	P	UB	1
<i>Andrena ilicis</i>	B ⁶	P	GS	1
<i>Andrena imitatrix</i>	B*	P	GS	1
<i>Andrena perplexa</i>	B*	P	DS	1
<i>Andrena rudbeckiae</i>	B ²⁹	A	GS	5
<i>Andrena simplex</i>	B ⁶	P	DS	1
<i>Andrena violae</i>	B ⁶	P	UB	2
<i>Andrena wilkella</i>	B*	P	DS	1
<i>Calliopsis andreniformis</i>	B ⁴⁴	A,P	DS,GS,UB	23
Apidae				
<i>Anthophora abrupta</i>	B ³⁰	A,V	DS	3
<i>Anthophora terminalis</i>	A ³⁴	V	DS,GS	5
<i>Anthophora walshii</i>	B ⁵¹	P	GS	1
<i>Apis mellifera</i>	A ⁴⁵	A,V,P	DS,GS,UB	1091
<i>Bombus auricomus</i>	B ⁹	V	DS,GS	5
<i>Bombus bimaculatus</i>	A ³⁵	A,V	DS,GS,UB	16
<i>Bombus fervidus</i>	A ³⁵	A,V	DS,UB	3
<i>Bombus fraternus</i>	B ¹⁶	A,V	DS,GS	2
<i>Bombus griseocollis</i>	B ¹⁷	A,V,P	DS,GS,UB	110
<i>Bombus impatiens</i>	B ³⁵	A,V	DS,GS,UB	39
<i>Bombus pensylvanicus</i>	A ³⁶	A,V,P	DS,GS,UB	107
<i>Bombus vagans</i>	A ³⁵	V	GS	1
<i>Cemolobus ipomoeae</i>	B ⁵⁰	V,P	DS,GS	3
<i>Ceratina calcarata</i>	A ^{28,43,47}	A,V,P	DS,GS,UB	51
<i>Ceratina dupla</i>	A ^{19,50}	A,V,P	DS,GS,UB	852
<i>Ceratina floridana</i>	A* ³⁷	A,V,P	DS,GS,UB	78

Table A.1 (cont.)				
Species of Bee	Nest Guild	Trap Method	Burn Treatment	Total Abundance
<i>Ceratina mikmaqi</i>	A ^{48,50}	A,V,P	DS,GS,UB	217
<i>Ceratina strenua</i>	B ⁴	A,V,P	DS,GS,UB	49
<i>Diadasia enavata</i>	B ⁵²	A	DS	1
<i>Eucera hamata</i>	B ⁵⁰	V,P	DS,GS	16
<i>Eucera rosae</i>	B*	V	GS	2
<i>Melissodes agilis</i>	B ³³	A,V,P	DS,GS,UB	67
<i>Melissodes bidentis</i>	B ⁶	V	DS,GS	4
<i>Melissodes bimaculata</i>	B ³⁸	A,V,P	DS,GS,UB	458
<i>Melissodes boltoniae</i>	B*	A,V	DS,GS,UB	5
<i>Melissodes communis</i>	B*	A,V,P	DS,GS,UB	35
<i>Melissodes comptoides</i>	B*	A,V,P	DS,GS,UB	87
<i>Melissodes coreopsis</i>	B*	A,V	DS,GS,UB	41
<i>Melissodes denticulata</i>	B*	A,V,P	DS,GS,UB	42
<i>Melissodes desponsa</i>	B*	A,V,P	DS,GS,UB	94
<i>Melissodes druriellus</i>	B*	A,V	DS,GS,UB	8
<i>Melissodes tincta</i>	B*	V	DS,GS	3
<i>Melissodes trinodis</i>	B ⁶	A,V	DS,GS,UB	10
<i>Melissodes vernoniae</i>	B*	A,V,P	DS,GS,UB	11
<i>Melissodes wheeleri</i>	B*	V	UB	1
<i>Melitoma taurea</i>	B ²⁷	V	DS,GS	4
<i>Nomada cressonii</i>	P ⁶	A	GS	1
<i>Peponapis pruinosa</i>	B ^{23,38}	V	DS,GS,UB	15
<i>Ptilothrix bombiformis</i>	B ⁴²	V,P	DS,GS,UB	82
<i>Svastra atripes</i>	B* ⁴⁰	V	DS	1
<i>Svastra obliqua</i>	B ^{39,41}	A,V,P	DS,GS	6
<i>Triepeolus concavus</i>	P*	A	GS	1
<i>Triepeolus cressonii</i>	P ⁶	A,P	GS	2
<i>Triepeolus donatus</i>	P ¹⁰	A	UB	1
<i>Triepeolus lunatus</i>	P ¹⁰	A,V	DS,GS	2
<i>Triepeolus simplex</i>	P*	A	DS	1
<i>Xenoglossa strenua</i>	B ⁴	V	GS,UB	3
<i>Xylocopa virginica</i>	A ²¹	A,V	DS,GS,UB	49

Table A.1 (cont.)				
Species of Bee	Nest Guild	Trap Method	Burn Treatment	Total Abundance
Colletidae				
<i>Colletes latitarsis</i>	B ⁶	P	DS	1
<i>Hylaeus affinis</i>	A ²²	A,V,P	DS,UB	3
<i>Hylaeus illinoisensis</i>	A ⁶	A	GS	2
<i>Hylaeus mesillae</i>	A ¹⁹	A,V,P	DS,GS,UB	46
<i>Hylaeus modestus</i>	A ⁶	A,V,P	DS,GS,UB	79
Halictidae				
<i>Agapostemon sericeus</i>	B ¹¹	A,V	DS,GS,UB	9
<i>Agapostemon texanus</i>	B ⁵⁰	V	GS	1
<i>Agapostemon virescens</i>	B ¹	A,V,P	DS,GS,UB	48
<i>Augochlora pura</i>	A ⁴⁶	A,V,P	DS,GS,UB	149
<i>Augochlora aurata</i>	B ⁴³	A,V,P	DS,GS,UB	600
<i>Augochlora persimilis</i>	B ³¹	A,V,P	DS,GS,UB	187
<i>Augochloropsis metallica</i>	B ⁴³	A,V,P	DS,GS,UB	24
<i>Augochloropsis sumptuosa</i>	B ⁴³	A,V	DS,GS,UB	8
<i>Halictus confusus</i>	B ⁵⁰	A,P	DS,GS,UB	11
<i>Halictus ligatus</i>	B ¹⁹	A,V,P	DS,GS,UB	401
<i>Halictus parallelus</i>	B ³²	A,V	DS,GS	5
<i>Halictus rubicundus</i>	B ¹⁹	A	GS	1
<i>Lasioglossum acuminatum</i>	B ⁶	V,P	DS,GS	3
<i>Lasioglossum admirandum</i>	B ¹³	P	DS	1
<i>Lasioglossum albipenne</i>	B ⁶	A,P	DS	2
<i>Lasioglossum bruneri</i>	B ^{14,28,43,47}	A,V,P	DS,GS,UB	140
<i>Lasioglossum callidum</i>	B ¹³	A,V,P	DS,GS,UB	92
<i>Lasioglossum coeruleum</i>	B ^{14,28,43,47}	P	DS	1
<i>Lasioglossum coreopsis</i>	B ^{14,28,43,47}	A,P	DS,GS,UB	6
<i>Lasioglossum coriaceum</i>	B ⁶	V	DS	1
<i>Lasioglossum cressonii</i>	A ⁶	A	GS,UB	2
<i>Lasioglossum hitchensi</i>	B ¹³	A,V,P	DS,GS,UB	412
<i>Lasioglossum imitatum</i>	B ⁶	A,V,P	DS,GS,UB	79
<i>Lasioglossum lineatulum</i>	B ⁶	V	DS,GS	2
<i>Lasioglossum nelumbonis</i>	B ⁶	V,P	UB	2

Table A.1 (cont.)				
Species of Bee	Nest Guild	Trap Method	Burn Treatment	Total Abundance
<i>Lasioglossum pectorale</i>	B ^{14,28,43,47}	P	GS	1
<i>Lasioglossum platyparium</i>	P ⁶	A,P	DS	3
<i>Lasioglossum pruinosum</i>	B*	P	UB	2
<i>Lasioglossum simplex</i>	B*	P	GS	1
<i>Lasioglossum smilacinae</i>	B ⁶	P	GS	1
<i>Lasioglossum tegulare</i>	B ⁶	P	DS	1
<i>Lasioglossum trigeminum</i>	B ¹³	A,V,P	DS,GS,UB	32
<i>Lasioglossum truncatum</i>	B ^{14,28,43,47}	V	DS	1
<i>Lasioglossum versatum</i>	B ^{14,28,43,47}	A,V,P	DS,GS,UB	942
<i>Lasioglossum weemsi</i>	B ⁶	P	GS	1
<i>Lasioglossum zephyrum</i>	B ⁶	A,V,P	DS,GS,UB	20
<i>Sphecodes pimpinellae</i>	P ⁵³	P	GS	1
Megachilidae				
<i>Ashmeadiella buconis</i>	A ²⁴	A	DS	2
<i>Coelioxys octodentata</i>	P ⁵⁴	V	DS	1
<i>Heriades leavitti</i>	A*	A,V	GS	2
<i>Heriades variolosa</i>	A ¹²	A	UB	1
<i>Hoplitis pilosifrons</i>	A ²⁶	V,P	DS,GS	9
<i>Hoplitis truncata</i>	A ⁶	V,P	DS,GS	2
<i>Megachile albitarsis</i>	A*	A,P	DS	2
<i>Megachile brevis</i>	A ²⁵	A,V	DS,GS,UB	15
<i>Megachile centuncularis</i>	A ¹⁹	A	DS,GS	4
<i>Megachile frugalis</i>	A*	A	GS	1
<i>Megachile inimica</i>	A ²⁰	A	DS,GS	2
<i>Megachile mendica</i>	B ^{3,49}	A,P	DS,GS,UB	10
<i>Megachile montivaga</i>	A ¹⁵	A	DS,UB	3
<i>Megachile parallela</i>	A*	A	GS	4
<i>Megachile petulans</i>	A ⁶	A	DS,GS,UB	5
<i>Megachile pugnata</i>	A ⁶	A	GS	1
<i>Osmia georgica</i>	A ⁵	A,P	DS,GS	3
<i>Stelis lateralis</i>	P ²⁶	A	GS	1

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APPENDIX B: CHAPTER 2 SUPPLEMENTARY TABLE

Table B.1: Invalid and accepted scientific names for species of bee in Illinois from the INHS database. Based on ITIS.gov and DiscoverLife.org

Invalid Names	Accepted Names
<i>Agapostemon cockerelli</i> (Crawford, 1901)	<i>Agapostemon obliquus</i> (Provancher, 1888)
<i>Agapostemon radiatus</i> (Say, 1837)	<i>Agapostemon sericeus</i> (Forster, 1771)
<i>Andrena chrysoceles</i> (Kirby, 1802)	No valid name found
<i>Bombus sapporoensis</i> (Cockerell, 1911)	<i>Bombus hypocrita</i> (Perez, 1905)
<i>Dialictus abanci</i> (Crawford, 1932)	<i>Lasioglossum abanci</i> (Crawford, 1932)
<i>Dialictus achilleae</i> (Mitchell, 1960)	<i>Lasioglossum achilleae</i> (Mitchell, 1960)
<i>Dialictus admirandus</i> (Sandhouse, 1924)	<i>Lasioglossum admirandum</i> (Sandhouse, 1924)
<i>Dialictus albipennis</i> (Robertson, 1890)	<i>Lasioglossum albipenne</i> (Robertson, 1890)
<i>Dialictus anomalus</i> (Robertson, 1892)	<i>Lasioglossum anomalum</i> (Robertson, 1892)
<i>Dialictus apocyni</i> (Mitchell, 1960)	<i>Lasioglossum apocyni</i> (Mitchell, 1960)
<i>Dialictus apopkensis</i> (Robertson, 1892)	<i>Lasioglossum apopkense</i> (Robertson, 1892)
<i>Dialictus atlanticus</i> (Mitchell, 1960)	<i>Lasioglossum hitchensi</i> (Gibbs, 2012)
<i>Dialictus brassicae</i> (Mitchell, 1960)	<i>Lasioglossum disparile</i> (Cresson, 1872)
<i>Dialictus bruneri</i> (Crawford, 1902)	<i>Lasioglossum bruneri</i> (Crawford, 1902)
<i>Dialictus coeruleus</i> (Robertson, 1893)	<i>Lasioglossum coeruleum</i> (Robertson, 1893)
<i>Dialictus connexus</i> (Cresson, 1872)	<i>Lasioglossum connexum</i> (Cresson, 1872)
<i>Dialictus coreopsis</i> (Robertson, 1902)	<i>Lasioglossum coreopsis</i> (Robertson, 1902)
<i>Dialictus cressonii</i> (Robertson, 1890)	<i>Lasioglossum cressonii</i> (Robertson, 1890)
<i>Dialictus fattigi</i> (Mitchell, 1960)	<i>Lasioglossum fattigi</i> (Mitchell, 1960)
<i>Dialictus flaveriae</i> (Mitchell, 1960)	<i>Lasioglossum flaveriae</i> (Mitchell, 1960)
<i>Dialictus foveolatus</i> (Robertson, 1902)	<i>Lasioglossum foveolatum</i> (Robertson, 1902)
<i>Dialictus genuinus</i> (Sandhouse, 1924)	<i>Lasioglossum versatum</i> (Robertson, 1902)
<i>Dialictus halophitum</i> (Graenicher, 1927)	<i>Lasioglossum halophitum</i> (Graenicher, 1927)
<i>Dialictus highlandicus</i> (Mitchell, 1960)	<i>Lasioglossum perpunctatum</i> (Ellis, 1913)
<i>Dialictus illinoensis</i> (Robertson, 1892)	<i>Lasioglossum illinoense</i> (Robertson, 1892)
<i>Dialictus imitatus</i> (Smith, 1853)	<i>Lasioglossum imitatum</i> (Smith, 1853)
<i>Dialictus junaluskenis</i> (Mitchell, 1960)	<i>Lasioglossum perpunctatum</i> (Ellis, 1913)
<i>Dialictus laevissimus</i> (Smith, 1853)	<i>Lasioglossum laevissimum</i> (Smith, 1853)
<i>Dialictus nigroviridis</i> (Graenicher, 1911)	<i>Lasioglossum nigroviride</i> (Graenicher, 1911)
<i>Dialictus novascotiae</i> (Mitchell, 1960)	<i>Lasioglossum novascotiae</i> (Mitchell, 1960)
<i>Dialictus nymphaearum</i> (Mitchell, 1960)	<i>Lasioglossum nymphaearum</i> (Robertson, 1895)
<i>Dialictus nymphalis</i> (Smith, 1853)	<i>Lasioglossum nymphale</i> (Smith, 1853)
<i>Dialictus oblongus</i> (Lovell, 1905)	<i>Lasioglossum oblongum</i> (Lovell, 1905)
<i>Dialictus obscurus</i> (Robertson, 1892)	<i>Lasioglossum obscurum</i> (Robertson, 1892)
<i>Dialictus perpunctatus</i> (Ellis, 1913)	<i>Lasioglossum perpunctatum</i> (Ellis, 1913)
<i>Dialictus pictus</i> (Crawford, 1902)	<i>Lasioglossum pictum</i> (Crawford, 1902)
<i>Dialictus pilosus</i> (Smith, 1853)	<i>Lasioglossum pilosum</i> (Smith, 1853)
<i>Dialictus pruiniformis</i> (Crawford, 1906)	<i>Lasioglossum semicaeruleum</i> (Cockerell, 1895)
<i>Dialictus pruinus</i> (Robertson, 1892)	<i>Lasioglossum pruinusum</i> (Robertson, 1892)

Table B.1 (cont.)	
Invalid Names	Accepted Names
<i>Dialictus rohweri</i> (Ellis, 1915)	<i>Lasioglossum versatum</i> (Robertson, 1902)
<i>Dialictus solidaginis</i> (Mitchell, 1960)	<i>Lasioglossum laevissimum</i> (Smith, 1853)
<i>Dialictus subversans</i> (Mitchell, 1960)	<i>Lasioglossum subversans</i> (Mitchell, 1960)
<i>Dialictus supraclypeatus</i> (Mitchell, 1960)	<i>Lasioglossum foveolatum</i> (Robertson, 1902)
<i>Dialictus tegularis</i> (Robertson, 1890)	<i>Lasioglossum tegulare</i> (Robertson, 1890)
<i>Dialictus testaceus</i> (Robertson, 1897)	<i>Lasioglossum testaceum</i> (Robertson, 1897)
<i>Dialictus unicus</i> (Sandhouse, 1924)	<i>Lasioglossum lineatulum</i> (Crawford, 1906)
<i>Dialictus versatus</i> (Robertson, 1902)	<i>Lasioglossum versatum</i> (Robertson, 1902)
<i>Dialictus vierecki</i> (Crawford, 1904)	<i>Lasioglossum vierecki</i> (Crawford, 1904)
<i>Dialictus viridatus</i> (Lovell, 1905)	<i>Lasioglossum viridatum</i> (Lovell, 1905)
<i>Dialictus weemsi</i> (Mitchell, 1960)	<i>Lasioglossum weemsi</i> (Mitchell, 1960)
<i>Dialictus wheeleri</i> (Mitchell, 1960)	<i>Lasioglossum wheeleri</i> (Mitchell, 1960)
<i>Dialictus zephyrus</i> (Smith, 1853)	<i>Lasioglossum zephyrum</i> (Smith, 1853)
<i>Hylaeus bisinuatus</i> (Forster, 1871)	<i>Hylaeus leptocephalus</i> (Morawitz, 1871)
<i>Hylaeus cressoni</i> (Cresson, 1907)	<i>Hylaeus mesillae</i> (Cockerell, 1896)
<i>Lasioglossum pectoralis</i> (Smith, 1853)	<i>Lasioglossum pectorale</i> (Smith, 1853)
<i>Melissodes rustica</i> (Say, 1837)	<i>Melissodes druriellus</i> (Kirby, 1802)
<i>Nomia heteropoda</i> (Say, 1824)	<i>Dieunomia heteropoda</i> (Say, 1824)
<i>Nomia triangulifera</i> (Vachal, 1897)	<i>Dieunomia triangulifera</i> (Vachal, 1897)
<i>Osmia coerulescens</i> (Linnaeus, 1758)	<i>Osmia caerulescens</i> (Linnaeus, 1758)
<i>Paralictus platyparius</i> (Robertson, 1895)	<i>Lasioglossum platyparium</i> (Robertson, 1895)
<i>Paralictus simplex</i> (Robertson, 1901)	<i>Lasioglossum simplex</i> (Robertson, 1901)
<i>Protandrena albitarsis</i> (Cresson, 1872)	<i>Pseudopanurgus albitarsis</i> (Cresson, 1872)
<i>Protandrena andrenoides</i> (Smith, 1853)	<i>Pseudopanurgus andrenoides</i> (Smith, 1853)
<i>Protandrena compositarum</i> (Robertson, 1893)	<i>Pseudopanurgus compositarum</i> (Robertson, 1893)
<i>Protandrena illinoiensis</i> (Cresson, 1878)	<i>Pseudopanurgus illinoiensis</i> (Cresson, 1878)
<i>Protandrena labrosiformis</i> (Robertson, 1898)	<i>Pseudopanurgus labrosiformis</i> (Robertson, 1898)
<i>Protandrena labrosus</i> (Robertson, 1895)	<i>Pseudopanurgus labrosus</i> (Robertson, 1895)
<i>Protandrena nebrascensis</i> (Crawford, 1903))	<i>Pseudopanurgus aestivalis</i> (Provancher, 1882)
<i>Protandrena ornatipes</i> (Cresson, 1872)	<i>Pseudopanurgus ornatipes</i> (Cresson, 1872)
<i>Protandrena parvus</i> (Robertson, 1892)	<i>Pseudopanurgus parvus</i> (Robertson, 1892)
<i>Protandrena pauper</i> (Cresson, 1878)	<i>Pseudopanurgus pauper</i> (Cresson, 1878)
<i>Protandrena rudbeckiae</i> (Robertson, 1895)	<i>Pseudopanurgus rudbeckiae</i> (Robertson, 1895)
<i>Protandrena simulans</i> (Swenk & Cockerell, 1907)	<i>Pseudopanurgus simulans</i> (Swenk & Cockerell, 1907)
<i>Protandrena solidaginis</i> (Robertson, 1893)	<i>Pseudopanurgus solidaginis</i> (Robertson, 1893)
<i>Stelis trypetina</i> (Cockerell, 1922)	<i>Stelis permaculata</i> (Cockerell, 1898)
<i>Triepeolus mesillae</i> (Cockerell, 1904)	<i>Triepeolus distinctus</i> (Cresson, 1878)