Insects as Indicators of Habitat Quality, Ecological Integrity and Restoration Success in Illinois Prairies, Savannas and Woodlands

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Summary

The typical methods that ecologists use for assessing habitat quality involves calculating quality based on primarily floristic data. This is true of evaluation of habitats in Illinois – although new methods have become available for assessing habitats based on other taxa. These alternative methods are often not in widespread use, especially in Illinois, and consist of using invertebrate indicator taxa to assess the ecological integrity of prairies, savannas, and woodlands (aquatic invertebrate survey tend to be more commonly used). There is a large diversity of invertebrates for which we have information on the life history, seasonality, and diet that live in these unique habitats. Critically, these organisms are often sensitive to environmental change and habitat fragmentation. Insects in particular can thus be valuable indicators of habitat quality and ecosystem integrity. For this study, we chose to look at four groups of insects as indicators, based on their life history, ease of identification, and knowledge of the co-authors. These groups are well represented in grassland biomes and include: (1) grasshoppers (Orthoptera: Acridoidea); (2) butterflies (Lepidoptera: Rhopalocera); (3) cicadas (Hemiptera: Cicadoidea); and (4) tiger beetles (Coleoptera: Carabidae). By looking at both the abundance and species diversity at a given site for each of these groups, we hoped to develop tools that would allow land managers to utilize these taxa as indicators of high quality prairie. This is not an entirely novel pursuit, grasshoppers and butterflies have consistently been shown to represent other invertebrate and plant taxa effectively in grasslands worldwide. Through this study we have developed a butterfly quality index tool for assessing sites. The taxa examined by our group also often rely on habitat quality that cannot be assessed by floristic data alone, for this we have gathered data on habitat heterogeneity.

Methods

Site selection

For this study we chose anywhere from low to high quality sites, including remnant and restored areas. These sites are further described in Table 1 and their locations throughout the state can be seen on Figure 1. Based on their size, several of these sites were divided up into multiple subsites, including the following: Beadles Barrens (three subsites), Stephen A Forbes State Recreation Area (two subsites), Ballard Nature Center (three subsites), Sand Prairie Scrub Oak Nature Preserve (two subsites), Iroquois County Conservation Area (two subsites), Richardson Wildlife Foundation (three subsites), and Green River State Wildlife Area (two subsites).

All areas were mapped using ArcGIS – outlines of areas designated as prairie were drawn and modified as needed (particularly after initial site visits). These areas were then given a buffer zone of five meters to avoid any edge effects. Within the central zone 50 randomized points were created using ArcGIS and loaded into GPS units for use in the field. Figure 2 illustrates both the buffer areas and randomized points of the three subsites at Beadles Barrens Nature Preserve. The randomized points were used for both trap site selection and transect start and end points.

Site visits

When possible, each site was visited by both teams (butterfly team and trap/transect team) a total of three times throughout the field season. The field season was initially defined as being between mid-May through early October, although after the first field season this was modified for the trap/transect team as most of the target taxa for this group (tiger beetles, cicadas, and grasshoppers) were found primarily after mid-June. At each visit, temperature, cloud cover, wind, and sampling time was recorded.

Traps

In order to catch a wide variety of insect taxa, both pitfall and pan traps were placed at each subsite. Traps were set up at six random locations throughout each sub-site (depending on size) and left for 24 hours. Given the smaller size of LCP and STB, only four locations were used at these sites. These traps included:

- Pitfall traps

- Two 12 ounce cups filled with soapy water placed in ground with 11 inch aluminum guide between each cup to lead insects to cup. Each cup has chicken wire placed on top to avoid the capture of vertebrates. These cups have proven effective at catching grasshoppers, crickets, spiders, and ground beetles (including tiger beetles).

- Pan traps
    - A 12-ounce plastic bowl (yellow, white, or blue) was placed on a three foot tall stand and filled with soapy water. This has proven to be effective at catching a diverse number of scarab beetles, flies, bees, and wasps.

Transect sweep netting

Random 50 meter transects were selected for each section of a site (See Table 1 for a list of sites and Figure 2 for an illustration of points generated for each subsite). After sweeping along the transect using a 15" diameter coleopterist net sweep samples were placed in "kill jars" charged with ethyl acetate. This has proven an effective method for collecting young grasshoppers, but in order to maximize the amount of adult grasshoppers caught we have also started placing white bowls along the transect overnight.

At 0, 10, 20, 30, 40 and 50 meters images of the vegetation are taken using a 1.5 x 1 meter white background of a 1 x 1 meter area. Vegetation in front of the area was lightly covered using a plywood board. This method helped us to quantify biomass without the need for taking large amounts of vegetation cuttings and quickly provides us with information on the height of the vegetation as well as the general cover of the vegetation. Also at 10 meter points, 12 ounce white bowls are laid at each 10 meter point and filled with soapy water. This method has proven effective at catching grasshopper and pygmy grasshoppers (Tetrigidae) along the transect that might not have otherwise been caught using the sweep (some species are more effective at fleeing or avoiding capture during sweeps).

Butterfly timed transects

In order to record butterfly species and abundance our sites, two individuals (Mike Jeffords and Sue Post) walked a randomized transect for thirty minutes to one hour (depending on size of site) and recorded each butterfly species and the number of individuals encountered. The sites chosen were the same for those where traps and transects were done (Table 1), but were completed on different dates. As the vast majority of butterfly species in Illinois can be identified by sight, this method negated the need for collecting large numbers of specimens and minimizes impact on local populations.

Habitat heterogeneity measurements

The method is based on a paper by Limb et al. (2007) in Rangeland Ecology & Management: "Digital Photography: Reduced Investigator Variation in Visual Obstruction Measurements for Southern Tallgrass Prairie". In figure 3, you can see an image taken at one of our sites, Iroquois County Conservation Area, of a meter by meter square of vegetation. Images were taken precisely three meters from the >1 meter by 1.5 meter backdrop, from 1 meter above the ground level. Using Photoshop, we can calculate the amount of vegetation (which includes both live and dead) by converting the image to black and white using the Threshold and Histogram tools. We will also calculate average vegetation height and other similar measures to correlate with species diversity of insect taxa.

Results and discussion

Cicada diversity

There are at least 20 species of cicadas in Illinois based on collection records at the Illinois Natural History Survey (INHS), and online records (bugguide.com). These twenty species fall into the following genera: *Neotibicen, Megatibicen, Okanagana, Cicadetta, Diceroprocta, Neocicada, Beameria,* and *Magicicada* (although it should be noted that there have been recent revisions of several of these genera). The conservation status of these species is unknown. Much of the locality information is dated (73% of databased cicadas in the Illinois Natural History Insect Collection were collected prior to 1970) and part of a landscape that has changed drastically over the past 150 years. Illinois is heavily dominated by agriculture and many species of cicadas are thought to be habitat specialists, some found only in areas with sandy soil (e.g. *Diceroprocta vitripennis,* Figure 5) or high quality prairies (e.g. *Okanagana balli*, *Cicadetta calliope,* see Figure 6), and many of these have very sparse records (only one to two locations for *O. balli*, *O. rimosa*, and *Beameria venosa*). The Wildlife Conservation and Restoration Program and the Illinois State Wildlife Grant Program created an Illinois Wildlife Action Plan (IWAP 2015) which lists three species of cicadas as species of greatest need of conservation (SGNC) – *D. vitripennis, O. balli,* and *Me. dorsatus.* Based on a sparse number of individuals caught during sweep-netting we propose that *Cicadetta calliope* might also be a species of concern.

We only found *D. vitripennis* at two of our sites: SRS and HAG, although we suspect it may also be at SPSO. *Me. dorsatus* was at several locations, including: HAG, LCP, BB, and SAF. *C. calliope* was only found at LCP, although it is a small species that emerges earlier in the season (mid-June). Although these species of cicada can emerge annually, many of these species are likely underground for several years (exact years unknown, suspected to be between two and nine for most species). In order to assess if these species are absent from a particular site, we would need to sample over a longer period. We have also added several new sites of known locations for *Me. dorsatus* and have collected tarsal clippings of individuals from several sites and multiple years that we hope to do population genetics studies on – however, we were unable to complete this work because a no-cost extension was not approved for this project. There are definitely **more surveys needed for this group of insects** that contributes to the summer soundscape and helps with nutrient cycling in prairies and other ecosystems.

Butterfly Quality Index (BQI)

Diversity and abundance data was collected for each site under investigation following the methods outlined above. The butterfly dataset amassed during the course of this project was significantly larger than anticipated and represents the largest such dataset ever compiled for butterflies in the state of Illinois. **Since a no-cost extension was not approved for this project, it was impossible to analyze the**

complete dataset, and so calculations were made for only two of the sites: (1) Carl N. Becker Savanna Nature Preserve (CBNP); and (2) Loda Cemetery Prairie Nature Preserve (LCP).

Two versions of the BQI were developed in order to provide tools for use when analyzing butterfly diversity and abundance data gathered during survey work at sites of interest. The equations used here to analyze the butterfly data follow those of Wallner (2013) which were developed for the analysis of similar Auchenorrhyncha datasets. Both versions of the BQI (dubbed BQI_a and BQI_b) provide a measure of habitat quality, but are calculated differently. BQI_a uses only diversity data and provides a rough, initial assessment, whereas BQI_b utilizes both diversity and abundance data, and therefore, provides a more rigorous measure of habitat quality. Both methods rely on the assignment of Coefficients of Conservatism (CC values) to each species recorded at a given site.

Coefficients of Conservatism for Illinois butterflies

Coefficients of Conservatism (CC) are values assigned to species based on a number of life history variables. The resulting figures reflect the level of conservatism of each species, with lower values indicating low conservatism and higher values indicating high conservatism. Species with higher conservatism are dependent on high quality habitats, and those with lower conservatism are less reliant on high quality habitats and regularly found in highly disturbed areas. Parameters taken into consideration when assigning CC values are: (1) voltinism (number of generations per year); (2) overwintering strategy; (3) host plant specificity (polyphagous, oligophagous, monophagous); and (4) habitat specificity. Values between 1 (not conservative) and 3 (conservative) are assigned for each of these parameters. Thus, a highly conservative species could have a CC value of 12, and an entirely non-conservative species a CC value of 4.

- Voltinism is significant as the fewer generations a species has, the narrower the window for populations to increase. Also, for species with only a single generation, the probability of extreme events (weather, etc.) impacting the populations is magnified. A species with one generation/year receives a value of 3; a species with two generations a year receives a 2; a species with more than 2 generations/years receives a 1.
- Overwintering strategy was chosen as this is perhaps the most vulnerable stage for butterflies and they are subject to both environmental factors (severe and unpredictable winter weather) and to the various management strategies (burning, land clearing, etc.) associated with Illinois landscapes. A species that does not overwinter in Illinois and must colonize from the south each year receives a value of 1. A species that overwinters as an adult receives a value of 2. This value

was chosen because butterflies overwintering as adults are known to be active when the temperatures are not too extreme and could move away from potential harm. Also, they tend to overwinter under tree bark and other areas above ground, so they would be less susceptible to burning regimes. A species that overwinters in any immobile state (egg, larva, or chrysalis) automatically receives a value of 3 as they are susceptible to whatever environmental factor occurs in their vicinity.

- Host plant specificity is significant as this can be a limiting factor for butterfly populations. Obviously the more general the food preferences, the more likely females are to find suitable host plants for their eggs. Therefore, polyphagous species receive a value of 1; those feeding on a relatively narrow range of host plants (single families or genera—oligophagous) receive a value of 2; while those feeding on only a single species of plant receive a value of 3.
- Habitat specificity is the most difficult parameter to assign to a species. Thus, relatively broad categories were chosen for the various butterflies. A species that is generally found in a great variety of diverse habitats (woods, open lands, wetlands, etc.) receives a value of 1; butterflies that predictably frequent a smaller category of habitats (open lands, various forest types) receive a value of 2; those species that are mostly habitat specific (wetlands of a given type, prairies) are given a value of 3.

Values were assigned for each of these parameters based on the known biology of each species (from the available literature) and the many years of field experience of by co-PIs Michael Jeffords and Susan Post. CC values for butterflies recorded at CBNP and LCP are presented in Tables 2 and 3.

Calculation of BQI_a

BQI_a is a simple method used to calculate a BQI using just species diversity data. Once a site has been surveyed and all butterfly species present recorded and assigned CC values, a surveyor has all the necessary data to calculate BQI_a. The index is calculated using the following equation (from Wallner 2013):

$$BQIa = meanCC \times \sqrt{Spp.}$$

in which:

meanCC = Mean coefficient of conservatism value for all species encountered per sampling effort (e.g. site, transect, plot).

√Spp. = Square root transformation of total no. species encountered at the site sampled.

This method generates an index value that is sufficient for initial assessment of the quality of the habitat at any given site, with higher values indicating higher quality sites. BQI_a was calculated for both CBNP and LCP using compiled butterfly survey data from 2015 and 2016. The results are presented in Table 4.

Calculation of BQI_b

BQI_b is a more involved method that takes into consideration both diversity and abundance data. It relies not only on the total number of species recorded at a given site, but the number of specimens encountered as a measure of population size. The index is calculated using the following equation (from Wallner 2013):

$$BQIb = \sum \left[\left(\frac{n_i}{N}\right) \times CC_i\right] \times \sqrt{Spp.}$$

in which:

n_i = Total number of individuals for species *i*.

N = Total number of individuals for all species.

CC_i = Coefficient of conservatism for species *i*.

√Spp. = Square root transformation of total no. species encountered at site sampled.

This method generates a more rigorous assessment of habitat quality at any given site, with higher values indicating higher quality sites. BQI_b was calculated for both CBNP and LCP using compiled butterfly survey data from 2015 and 2016. The results are presented in Table 5.

Discussion and conclusion of BQI data

BQIs calculated for CBNP and LCP show significant differences between the two sites with both BQI_a and BQI_b values being higher at CBNP than at LCP. This suggests that the habitat at CBNP is of higher quality than that at LCP. BQI_a and BQI_b for CBNP and LCP differed by 9.05 and 7.19 respectively, demonstrating that both methods generate comparable values. Despite LCP generally being regarded as a very high quality site from a botanical perspective (Sivicek and Taft 2011), the lower BQI values suggest that it may be a less favorable habitat for butterflies than other "lower quality" sites. There could be several reasons for this, including aspects of floristic diversity, physical structure of the habitat, and the extent of its isolation from suitable surrounding habitat. For example, LCP is very isolated,

whereas CBNP is less so. Computation of BQIs and structural indices (see below) using the large datasets generated for every site surveyed during this project would undoubtedly shed light on some of these questions. **However, this was not possible since a requested no cost extension was not granted**.

Grasshopper diversity

Overall, we found a striking lack in diversity of grasshoppers at the sites chosen for this project. As we have not completed the habitat heterogeneity structural quality index (described in the next section), we cannot compare diversity of grasshoppers to the index at this time. As such, we will make several comments on the notable species of grasshoppers seen as part of this project. Both *Arphia xanthoptera* and *A. sulphurea* were found reliably at most sites from our northernmost site (RWF) to our southernmost (STB). *Chortophaga viridifasciata* was also found at most sites (RWF, BNC, SAF, SRS, SPSO, GR, LCP, CBNP, ICCA, WB) and throughout the entirety of the field season. Although not caught during a transect sample, *Encoptolophus sordidus* was only recorded at LCP. The longhorn bandwing grasshopper, *Psinidia fenestralis* was only found late in the season at two sites: BNC and HAG. The orange-winged grasshopper, *Pardalophora phoenicoptera*, was found throughout the sand prairies (SRS, HAG, SPSO). The mottled sand grasshopper, *Spharagemon collare,* was found at BNC, HAG, and SPSO. A related species, Boll's grasshopper or *Spharagemon bolli* was found at BNC and SPSO. Several of the bandwing grasshoppers were seen more commonly in the parking lots of sites or in nearby urban parks – including *Dissosteira carolina* (RWF, SRS, STB) and *Hippiscus ocelote*.

Although not a bandwing grasshopper, the American Grasshopper, *Schistocerca americana* was only found at one of the sites, BB. A diversity of Melanoplines (not bandwings) were captured, but identification of this group can be difficult and was outside of the scope of this project.

Habitat Heterogeneity Structural Quality Index

This data is still being compiled for all sites, however, an initial review of the habitat heterogeneity values for the 2015 field season indicates that at LCP there is very little open space in the bottom quadrant analyzed (below 0.375 meters). At LCP we found up to 99.7% coverage in the bottom quadrant, with the lowest percent coverage at 82.4%. This contrasted with CBNP where we found an average of 58.6% coverage in the bottom quadrant, with a much greater degree of variability (values ranged from 29.0% to 89.2%). This might correspond with our finding of a shockingly low number of ground beetle species – over the multiple years of this study, zero tiger beetles (Coleoptera: Carabidae: Cicindelinae), and a total of four ground beetle species (Coleoptera: Carabidae) were captured at LCP. This contrasts to CBNP, where we found ten species of ground beetles, including one tiger beetle species. We suspect that would

be strong correlations between habitat heterogeneity values and species richness at our sites as a result of life histories. Ground beetles rely on open space for hunting, cicadas need vegetation structure for emergence and calling, and grasshoppers need open areas for oviposition and mating displays.

Objectives and Status

Objective 1: Identify at least three representative prairie, savanna and woodland habitats in IL and their associated grasshopper, butterfly, cicada and tiger beetle species (focal taxa). This will be completed by December 2014. Existing data from sites identified in the Illinois Natural Areas Inventory (INAI) and Critical Trends Assessment Program (CTAP) will be reviewed during the early stages of the project in order to help identify potential sites for more detailed study (details are described in Job 1 and the Project Schedule).	**Status of Objective 1:** We identified 13 areas in Illinois (Table 1) to collect and observe grasshopper, butterfly, cicada, and tiger beetle species.
Objective 2: Establish monitoring programs relevant to IDNR managers and Citizen Science Groups (e.g. Master Naturalists) for the focal taxa in IL. Setup of the monitoring programs will be completed by the 31 May 2015 with monitoring running throughout the duration of the project. Sites for continual monitoring will be identified following completion of Objective 1 in order to ensure coverage of all salient habitat types and qualities (details are described in Job 2 and the Project Schedule).	**Status of Objective 2:** Sam Heads led a grasshopper identification workshop for the public directly prior to the start of this grant (August 2014). This workshop was sponsored by both the Illinois Audubon Society and the Illinois Nature Preserves Commission. One of the sites that we identified in Objective 1 was chosen as a result of this workshop (Sand Prairie Scrub Oak) as attendees helped to identify some more rare species of grasshoppers at this site. In April of 2016, we cohosted an event with the Chicago Academy of Sciences and the Illinois Butterfly Monitoring Network (IBMN) to extend the range covered by IBMN volunteers beyond the greater Chicago area. Although we have access to the information compiled by the IBMN from both 2015 and 2016 field seasons, we have not had time to evaluate this information as regards to this grant as we were not granted a no-cost extension. The sites described in Objective 1 were instead monitored by grant co-authors as well as both paid and volunteer undergraduate students.
Objective 3: Identify and characterize those species and species assemblages of the focal taxa (four groups comprising grasshoppers, butterflies, cicadas and tiger beetles) that are potentially valuable as indicators of habitat quality and ecosystem integrity in IL prairie, savanna and woodland environments. This will be completed by 31 July 2017 (details are described in Job 3 and the Project Schedule).	**Cicadas:** We determined that of the 20 species of cicadas found in Illinois, there are several taxa that are severely restricted in distribution and abundance in prairies. These species include: *Diceroprocta vitripennis*, *Beaumeria venosa*, *Cicadetta calliope*, *Okanagana balli*, and *Megatibicen dorsatus*. We suspect that several of these species are found only in undisturbed areas due to their life history which requires years of

	undisturbed development underground -- as such they are typically only found in remnant prairies. We found that collecting cicadas by net was incredibly difficult, if not impossible; however, many of these species can reliably be identified by the male chorus (audible song). We are also working on methods for identification of cicadas based on the DNA found in their exuviae ("shell") and have had initial success, but were not able to complete this project as we were not granted a no-cost extension. As partially detailed in the results, more work is needed in this group, including long-term audio monitoring and population genetics work. **Butterflies**: We developed coefficients of conservatism (CC) for those species listed in Tables 2 and 3, although we did not assign values for species not found at sites outside of Loda Cemetery Prairie or Carl Becker Nature Preserve as we were not granted a no-cost extension. **Tiger beetles**: We determined that although there may be merit in utilizing tiger beetles as indicators of a habitat quality we did not capture a sufficient number of individuals using our traps. They were not found frequently at our sites using pitfall traps as our points were placed randomly and we found that this taxonomic group is often highly localized within prairies. **Grasshoppers**: Several species of grasshoppers were strikingly absent from our sites, indicating that the diversity of grasshoppers in Illinois may likely be in decline although we have not had time to further analyze this data as we were not granted a no-cost extension. **Other insects/arthropods**: With our sampling methodology, we captured a wide diversity of pollinators, including bees (Table 6) and flies. *Bombus affinis* has been recently listed as a critically endangered species. It should be noted that at none of our sites did we observe or capture any *B. affinis*, although they have been seen at one of our sites in the past (RWF, 1996). Most of our bee by-catch has been pinned and curated, but not identified.
Objective 4: Develop at least one tool for each habitat to assess the success of IDNR restoration	Two tools were developed from previously described methods in order to assess IDNR sites

efforts in IL prairies, savannas and woodlands using the identified species/assemblages by 31 July 2017 (details are described in Job 4 and the Project Schedule).	utilizing butterfly survey data and vegetation analysis compiled by this study: including the Butterfly Quality Index and the Habitat Heterogeneity Quality Index. Both of these indices have not been used for all data collected during the grant period as we were not granted a no-cost extension.
Objective 5: Write reports and manuscripts. Quarterly and annual reports and a final report will be provided at the time specified in the grant agreement (details are described in Job 5 and the Project Schedule).	Quarterly and annual reports were submitted for this grant. Data analysis and manuscript preparation are still in progress and will be delayed as a result of not being granted a no-cost extension.

References

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Tables and figures

Table 1. Site list of representative prairies chosen in Illinois for this study including abbreviations used in this report and the county in which they are located. See figure 1 for a map of these sites.

Map Number	Abbrev.	Site Name	County
1	BB	Beadles Barrens	Edwards
2	SAF	Stephen A Forbes State Recreation Area	Marion
3	BNC	Ballard Nature Center	Effingham
4	LCP	Loda Cemetery Prairie Nature Preserve	Iroquois
5	SRS	Sand Ridge State Forest	Mason
6	HAG	Henry Allan Gleason Nature Preserve	Mason
7	SPSO	Sand Prairie Scrub Oak Nature Preserve	Mason
8	ICCA	Iroquois County Conservation Area	Iroquois
9	CBNP	Carl Becker Nature Preserve	Iroquois
10	RWF	Richardson Wildlife Foundation	Lee
11	WB	War Bluff Valley Sanctuary	Pope
12	GR	Green River State Wildlife Area	Lee
13	STB	Simpson Township Barrens Natural Area	Johnson

Table 2. Coefficient of Conservatism (CC) values for butterfly species recorded at LCP. Abbreviations are as follows: V, voltinism; OS, overwintering strategy; HPS, host plant specificity; HS, habitat specificity.

Species	**V**	**OS**	**HPS**	**HS**	**CC**
Black Swallowtail (*Papilio polyxenes*)	1	3	2	2	8
Giant Swallowtail (*Papilio cresphontes*)	2	3	2	2	9
Clouded Sulphur (*Colias philodice*)	1	3	2	2	8
Alfalfa Butterfly (*Colias eurytheme*)	1	3	2	2	8
Cloudless Sulphur (*Phoebis sennae*)	1	1	2	2	6
Checkered White (*Pontia protodice*)	1	3	2	2	8
Little Yellow (*Pyrisitia lisa*)	1	1	2	2	6
Eastern Tailed Blue (*Cupido comyntas*)	1	3	2	1	7
Gray Hairstreak (*Strymon melinus*)	1	3	1	2	7
Summer Azure (*Celastrina neglecta*)	1	3	1	1	6
American Snout (*Libytheana carinenta*)	1	1	3	2	7
Red Admiral (*Vanessa atalanta*)	1	1.5	2	2	6.5
Painted Lady (*Vanessa cardui*)	1	1	1	2	5
American Painted Lady (*Vanessa virginiensis*)	1	1.5	2	2	6.5
Common Buckeye (*Junonia coenia*)	1	1	1	2	5
Viceroy (*Limenitis archippus*)	1	3	2	2.5	8.5
Pearl Crescent (*Phyciodes tharos*)	1	3	2	2	8
Monarch (*Danaus plexippus*)	1	1	2	2	6
Common Wood Nymph (*Cercyonis pegala*)	3	3	2	2	10

Table 3. Coefficient of Conservatism (CC) values for butterfly species recorded at CBNP. Abbreviations as for table 2.

Species	V	OS	HPS	HS	CC
Spicebush Swallowtail (*Papilio troilus*)	2	3	2	2	9
Black Swallowtail (*Papilio polyxenes*)	1	3	2	2	8
Pipevine Swallowtail (*Battus philenor*)	1	3	2	2	8
Tiger Swallowtail (*Papilio glaucus*)	1	3	1	2	7
Clouded Sulphur (*Colias philodice*)	1	3	2	2	8
Alfalfa Butterfly (*Colias eurytheme*)	1	3	2	2	8
Cloudless Sulphur (*Phoebis sennae*)	1	1	2	2	6
Checkered White (*Pontia protodice*)	1	3	2	2	8
Little Yellow (*Pyrisitia lisa*)	1	1	2	2	6
Eastern Tailed Blue (*Cupido comyntas*)	1	3	2	1	7
Gray Hairstreak (*Strymon melinus*)	2	3	1	2	8
Bronze Copper (*Lycaena hyllus*)	1	3	2	2.5	8.5
American Snout (*Libytheana carinenta*)	1	3	2	2	8
Painted Lady (*Vanessa cardui*)	1	1	3	2	7
American Painted Lady (*Vanessa virginiensis*)	1	1	1	2	5
Common Buckeye (*Junonia coenia*)	1	1.5	2	2	6.5
Viceroy (*Limenitis archippus*)	1	1	1	2.5	5.5
Pearl Crescent (*Phyciodes tharos*)	1	3	2	2	8
Great Spangled Fritillary (*Speyeria cybele*)	3	3	2	2	10
Regal Fritillary (*Speyeria idalia*)	3	3	2	2.5	10.5
Aphrodite Fritillary (*Speyeria Aphrodite*)	3	3	2	2	10
Silver-bordered Fritillary (*Boloria selene*)	2	3	2	2.5	9.5
Meadow Fritillary (*Boloria bellona*)	2	3	2	2	9
Monarch (*Danaus plexippus*)	1	1	2	2	6
Common Wood Nymph (*Cercyonis pegala*)	3	3	2	2	10

Table 4. BQI_a values for CBNP and LCP calculated using diversity data from butterfly surveys carried out in 2015 and 2016.

Site Name	meanCC	√Spp.	BQI_a
Loda Cemetery Prairie Nature Preserve (LCP)	7.13	4.36	31.09
Carl N. Becker Savana Nature Preserve (CBNP)	7.87	5.10	40.14

Table 5. BQI_b values for CBNP and LCP calculated using both diversity and abundance data from butterfly surveys carried out in 2015 and 2016.

Site Name	**$\Sigma[(n_i/N)\times CC_i]$**	**$\sqrt{}$Spp.**	**BQI_b**
Loda Cemetery Prairie Nature Preserve (LCP)	7.78	4.36	33.92
Carl N. Becker Savvana Nature Preserve (CBNP)	8.06	5.10	41.11

Table 6. Bumble bee species found at each site (see Table 1 for abbreviations). Records are from pan traps, transects, or hand-caught using nets.

	BB	SAF	BNC	LCP	SRS	HAG	SPSO	ICCA	CBNP	RWF	WB	GR
Bombus bimaculatus	x	x				x			x		x	
B. griseocolis	x								x			
B. impatiens	x	x			x		x		x	x		x
B. pensylvanicus		x				x						x
B. perplexus							x					
B. rufocinctus						x						
B. vagans			x					x				

Figure 1. Map of sites used for is study. 1 – Beadles Barrens Nature Preserve (BB); 2 – Stephen A. Forbes State Recreation Area (SAF); 3 – Ballard Nature Center (BNC); 4 – Loda Cemetery Prairie Nature Preserve (LCP); 5 – Sand Ridge State Forest (SRS); 6 – Henry A. Gleason Nature Preserve (HAG); 7 – Sand Prairie Scrub Oak Nature Preserve (SPSO); 8 – Iroquois County Conservation Area (ICCA); 9 – Carl Becker Nature Preserve (CBNP); 10 – Richardson Wildlife Foundation (RWF); 11 – War Bluff Sanctuary (WB); 12 – Green River State Wildlife Area (GR); and 13 – Simpson Township Barrens (STB).

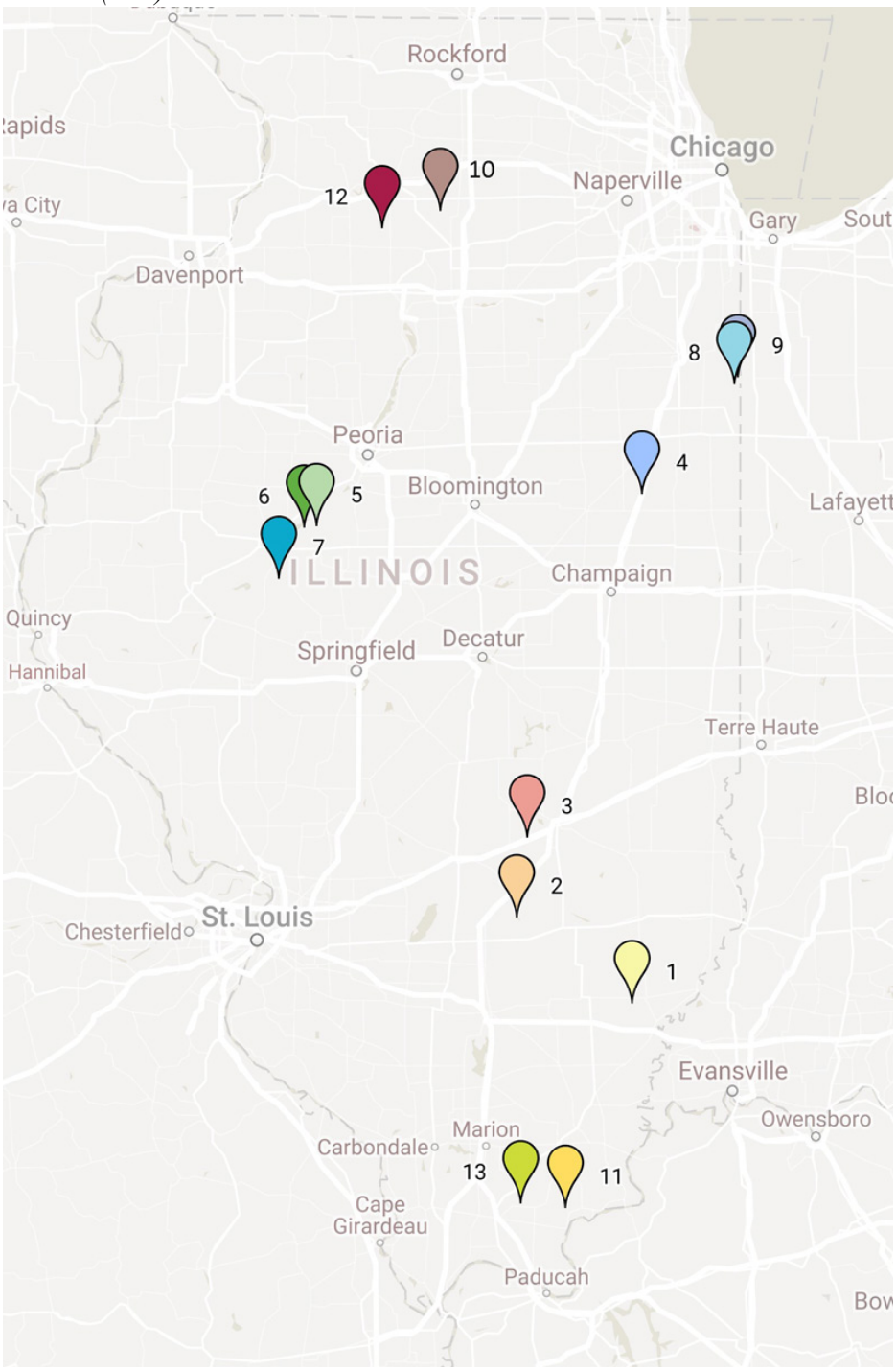
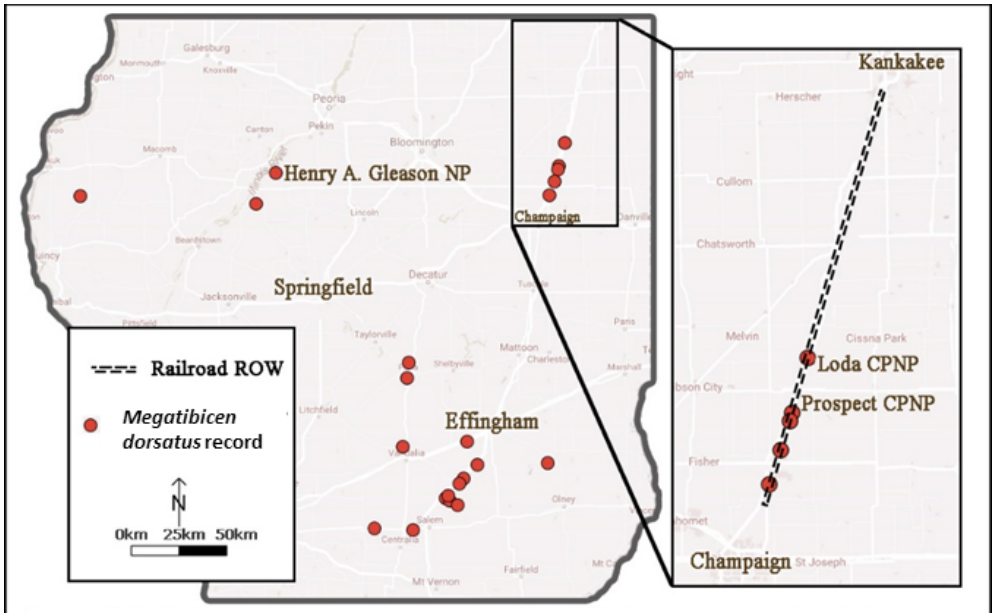


Figure 2. Beadles Barrens showing example of buffer zones (outer perimeter) and randomized points obtained using ArcGIS.

Figure 3. Illustration of percent coverage calculation to assess habitat heterogeneity. A 1 meter by 1.5 meter board tarp was placed at every 10 meter point along a randomly placed 50 meter transect. Vegetation was flattened using a plywood board (can be seen in the first image) one meter in front of the tarp in order to only measure a 1 meter square plot of vegetation. Using the threshold tool in Adobe Photoshop a black and white image was created. The histogram function of ImageJ allowed calculation of percent coverage.

Figure 4. Partial map of Illinois showing known records of Megatibicen dorsatus based on findings from this study and records found in the Illinois Natural History Survey Insect Collection.



Partial map of Illinois showing records of *Megatibicen dorsatus* (red dots) from personal observations and INHS Insect Collection records. Railroad rights-of-way that follow US 45 are indicated in dashed lines north of Champaign.

Figure 5. Diceroprocta vitripennis distribution in Illinois based on findings from this study (Henry Allen Gleason NP and Sand Ridge State Forest) and records found in the Illinois Natural History Survey.

Figure 6. Cicadetta calliope distribution in Illinois based on findings from this study (Loda Cemetery Prairie) and records found in the Illinois Natural History Survey.