Resources for monarch butterfly larvae and adults across Illinois grasslands

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Executive Summary

We quantified the resources available to monarch butterflies (*Danaus plexippus*) and other pollinators in grasslands found on properties owned by the Illinois Department of Natural Resources (DNR), and across the state of Illinois. The resources we focused on were blooming species for flower-visiting adults, and milkweeds (subfamily Asclepiadoideae) for monarch larvae. Our work included an observational portion, experimental transplanting, and analysis of a long-term data set.

In our assessment of floral resources on DNR properties, we found that blooming species abundance and diversity were greater in sites with active grassland management, such as burning or invasive and woody species removal. The boost in blooming species was more pronounced later in the growing season. Grassland restorations and the category of 'hay/old fields' tended to have lower blooming species diversity than the few remnant prairies we could sample, especially early in the growing season. While blooming abundance in restorations was high late in the growing season, it was largely driven by a few common species (especially *Solidago canadensis*, Canada goldenrod).

We also analyzed data from the Critical Trends Assessment Program (CTAP) that covered 1997 to 2021. Data were collected from randomly selected sites across the state that were revisited every five years. Most sites are privately owned. We took the data made available by CTAP and characterized trends in the abundances of species that attract bees, lepidopterans, and beetles to their flowers. We found evidence that floral resources are increasing per unit area of grasslands, though this is counterbalanced by the overall trend for grasslands loss in Illinois. The abundance of floral resources in wetlands and forests is generally declining.

When analyzing trends in milkweed abundance across DNR sites, we found that the most abundant and widespread species were *Asclepias syriaca* (common milkweed) and *A. verticillata* (whorled milkweed). We found that *A. verticillata* was more likely to be present in the northern and western parts of the state, which is consistent with the overall species distribution. We found greater densities of *A. syriaca* in southern sites, in hayfields or old fields, and much lower densities in remnant prairies. Milkweed abundance was not strongly associated with any grassland management action we recorded.

From 2020 to 2022, we checked over 25000 spontaneously occurring milkweeds for monarch eggs and larvae, and found over 600 neonates (we refer to eggs and larvae together as 'neonates'). Across all years, the vast majority (>93%) of the neonates we found were on *A. syriaca*, although we checked approximately the same number of *A. verticillata*. We found more

neonates per plant at northern sites and at sites with lower milkweed densities, and both relationships remained intact when we made efforts to untangle the correlation between latitude and milkweed density. We found only weak, inconsistent relationships between monarch oviposition and blooming species availability. Additionally, 2022 was a very bad year for monarch reproduction at our study sites.

While collecting observational data on blooming species, milkweed density, and monarch larvae, we also observed over 500 adult monarchs, and correlated the number observed per site visit with site characteristics. In the early and middle portion of the summer, we found more adult monarchs at sites with more milkweeds, and a greater diversity of blooming plant species. At the end of the season, we found more adult monarchs at sites with greater floral abundance, likely because those adults are preparing for migration south. At the beginning and end (but not the middle) of the field season, we found more monarchs at sites with less human development within 5 km.

We also planted two species of milkweed (*A. incarnata* and *A. tuberosa*, i.e., swamp milkweed and butterfly milkweed) into different settings on DNR properties. Most of the sites with transplanting were included in the observation portion, but some were plantings in lawns, which was meant to mimic a garden setting. Milkweeds planted on lawns had more neonates than those found in grasslands. Milkweeds planted in small patches had fewer milkweeds on them in grasslands, but more milkweeds on them in lawns. We suspect the shift in monarch oviposition preference is likely due to increased detectability of large patches in grasslands with complex and obstructive vegetation, but on lawns where all plants are highly detectable female monarchs are avoiding large milkweed patches that may have greater disease, predation, or competition. Finally, among transplanted *A. incarnata* placed in grasslands, there were more monarch neonates at sites with greater abundances of blooming plants.

Our work characterized the resources available to monarch butterflies, and other pollinators, on DNR properties. We also found patterns of where and when those resources are promoted, and where monarch butterflies are most likely to use habitat. Also, our work highlighted gaps in knowledge about site management history.

Project Timeline: Proposed and Actual

The accomplishments during the project period largely followed the timeline originally proposed. See Table 1 for a comparison of the proposed and actual actions associated with the timeline. There were delays and changes to planned actions, often due to direct and indirect effects of Covid-19. Nonetheless, the overall project goals were met and exceeded. Specifically, multiple levels of data on grasslands found on Illinois Department of Natural Resources (DNR) property were collected. Most data were collected using the Integrated Monarch Monitoring Program (IMMP) protocols published by Monarch Joint Venture. These protocols cover pollinator (floral) resources, milkweed stems, and monarch butterfly habitat usage (mostly via documenting oviposition). We collected data at 49 sites, with 46 of those sites visited in multiple years. This total exceeded what we originally proposed, 40 sites with multiple years of sampling. We also planted 3200 milkweeds at 66 unique sites (after discarding data from two sites), and checked them for monarch oviposition four to six times per field season. We supplemented our findings on pollinator plants on DNR properties with an analysis of a larger, long-term data set from the Critical Trends Assessment Program, and tested trends in the abundance of plant species associated with various guilds of insect floral visitors.

Accomplishments

Objective 1 - Quantify floral resources

We used the Integrated Monarch Monitoring Program's protocols to quantify floral resources at 49 unique grasslands on 29 DNR properties (Figure 1, see Table 2 and Appendix 1 for information on each study site). Specifically, we completed IMMP's 'Activity 1A'. Forty-six of these grasslands had visits in multiple years. When quantifying floral resources, we included 'blooming' plant species with flowers that appear to rely on floral visitors for pollination. Thus, we excluded many wind-pollinated flowering plants, mostly grasses. We quantified floral resources at grasslands three times per year, except in 2020 when we had two quantitative measures plus

one estimate of floral resources during the early sampling period (June). There were fewer quantitative sampling events in 2020 due to restrictions associated with Covid-19, though we still met the minimum goals set out in the proposal.

We quantified floral resources using the IMMP protocol during 243 site visits (mean of 4.96 visits per site). Additionally, in June of 2020 we *estimated* floral resources at 21 sites. During floral resource quantification, we identified 247 blooming plant species and recorded 21 unknown species. In total we have over 1700 records collected with this part of the IMMP protocol, an average of 7.1 species recorded per site visit. The data for each site are included as a supplementary data set, described below and in the Appendix. We calculated measures of floral diversity and abundance, discussed in the Methods.

Additionally, we used an external data set to attempt to quantify trends in the abundance of plants that are important to pollinators across Illinois. We used the Critical Trends Assessment Program (CTAP) data set. CTAP is a long-term monitoring program that surveys multiple taxa, and includes in-depth vegetation cover estimates at randomly selected study sites that are revisited every five years (Carroll. et al. 2002) This data set has been helpful for estimating the quantity of milkweed resources of monarch butterflies (Zaya et al. 2017) and floral resources for bumble bees (Mola et al. 2021). We classified the likely floral visitors for 850 of the nearly 1500 plant species encountered in the CTAP database over 20 years, with the goal of describing how the cover of plant species with flowers attractive to three groups of insects (bees, lepidopterans, beetles) changed through time. We believe that the method has some limitations because of the breadth of the insect categories used and the absence of importance values for different floral resources (e.g., frequency of visitation), but there is value in the assessment of overall trends. Further details are in the Methods and Results, below.

Objective 2 - Quantify milkweed densities

We used the IMMP protocol to quantify the abundance of milkweeds at every site where we quantified floral resources (Table 2). This part of the IMMP protocol was also included under 'Activity 1A'. Milkweed abundance estimates were measured along transects and in quadrats during 243 site visits to 49 sites, with 2-3 annual visits to each site, and multiple years for 46 sites. In total we counted over 24000 milkweeds from nine species along our transects (*Asclepias syriaca*, 48 sites; *A. verticillata*, 17 sites; *Cynanchum laeve*, 6 sites; *A. tuberosa*, 4 sites; *A. incarnata*, 4 sites; *A. hirtella*, 4 sites; *A. viridis*, 3 sites; *A. viridiflora*, 2 sites; *A. purpurascens*, 1 site). Estimates of milkweed density across visits to the same site were sometimes inconsistent, for multiple reasons:

a) Slight shifts in transect position between visits could affect the encounter rate of clonal, highly clumped species. This is especially the case for *A. verticillata*.

b) We modified the protocol for estimating milkweed abundance after 2020. For some sites in 2020, the area over which milkweed abundance was measured was one-tenth of the area in which milkweeds were counted in the other years of the study (this is not true for all sites). The change in 2021 and 2022 may not directionally bias the milkweed estimates, but it makes them more reliable than in 2020.

c) Human error may have led to underestimates of milkweed density during some site visits if individuals were not spotted or not identified correctly. This is most relevant to *A. verticillata*, which has inconspicuous grass-like leaves, and looks different from other milkweeds. The Covid-19 pandemic likely increased the role of human error in 2020 and part of 2021, due to restrictions on traveling in groups and health problems for key personnel.

A major goal was to tie milkweed abundance to site management practices, history, and other characteristics. We contacted DNR staff—typically the site Superintendent, District Heritage Biologist, and District Wildlife Biologist—to obtain information about site management and history. It was a challenge to collect reliable information on site management and history.

We could often confirm whether a practice was applied to a site (prescribed fire, mowing, herbicide and other invasive control), but had a more difficult time in confirming that a practice was *not* applied to a site. Additionally, information on species seeded into restorations was limited. Nonetheless, we were able to gather a large amount of management information history, summarized in Table 2 and in Appendix 1.

Objective 3 – Quantify monarch butterfly habitat use

We used two approaches to quantify monarch habitat usage, with emphasis on monarch oviposition. The work for Objective 3 fell into two categories. First, an observational portion concentrated on the 49 sites mentioned above (Table 2, Figure 1), and was conducted at the same time as the work of Objective 1 and 2. Second, an experimental portion included the majority of the sites above. We added additional experimental sites on mowed lawn areas on DNR property near other study grasslands (Table 3, Figure 2).

The observational approach for quantifying monarch butterfly oviposition utilized 'Activity 2' from the IMMP protocol. We checked for monarch eggs and larvae on milkweed plants at the study site. The majority of these milkweeds were found along the transect, but when the number of milkweeds was low (fewer than 30) we supplemented with observations away from the transect. However, when milkweeds were not found along the transect it was usually also difficult to find them away from the transect. In total we searched for eggs or larvae on over 25000 milkweeds. *Asclepias syriaca* was found at the most sites (48 sites, over 10000 stems), but more stems of *A. verticillata* were encountered (16 sites, nearly 14000 stems). The other eight milkweed species encountered were found at a maximum of six sites, and had fewer than 330 stems encountered. The other eight species encountered were most of the same ones as in Objective 2 (*A. incarnata*, *C. laeve*, *A. viridiflora*, *A. tuberosa*, *A. hirtella*, *A. viridis*, *A. purpurascens*), but *A. sullivantii* was a new species not encountered under the previous Objective. While checking milkweeds for monarch butterfly neonates (eggs and larvae), we

found 659 neonates across the three years. The majority (613) were found on *A. syriaca*, which is consistent with the findings in previous works (e.g., Seiber et al. 1986, Pocius et al. 2018). It was evident in our data set that 2022 was a poor year for monarch butterfly abundance in Illinois, as the rate at which neonates were found was approximately one-third of that in the other years (details in Results). This is consistent with observations from other monarch butterfly researchers about the size of the 2022 summer population (Lovett 2022, Taylor 2022), and may have been associated with unusually cold weather conditions during northern migration in 2022 (Zylstra et al. 2021, Taylor 2022).

The experimental portion of the study involved planting young milkweed plants at field sites and checking for monarch eggs and larvae. This technique allowed for control of milkweed condition, age, species, and patch size. We planted 3200 milkweeds at 66 sites (Figure 2). The milkweeds planted were *A. incarnata* (2700 plants) and *A. tuberosa* (500). The original proposal suggested using *A. incarnata* and possibly *A. syriaca*, but previous experience showed that *A. syriaca* has a low survival rate when being transplanted, and *A. tuberosa* is better adapted to the soils found at some of the study sites. The experimental portion also included a test of patch size and its effect on monarch oviposition. *Asclepias incarnata* individuals were planted in three different patch sizes: a single plant, four plants, and 16 plants. The original proposal suggested the ‘medium’ patch might include five plants and the ‘large’ patch might include 25 plants, but the numbers were reduced due to logistical (and budgetary) constraints. The 66 sites included all but five of the sites covered in the work associated with Objective 1 and 2. The five sites where we did not plant milkweeds were Illinois Nature Preserves. Additionally, there were 22 lawn sites at DNR properties meant to serve a similar role to gardens, that is, separated from natural areas. In total, we made 1188 observations of monarch neonates during this part of the study, including 374 larvae. The vast majority of neonates (1162, 97.8%) were found on *A. incarnata*.

While collecting data on blooming species, milkweed density, and monarch oviposition, we also made observations of adult monarchs during site visits. We include an analysis of the number of adult monarchs observed during each site visit, with connections made to site characteristics and temporal patterns.

Methods

Objective 1 - Quantify floral resources

Field observations at DNR properties (Objective 1a)

When quantifying floral resources at study sites, we relied on the Integrated Monarch Monitoring Program protocol, under Activity 1, Option A (Monarch Joint Venture 2021).

Properties that had potential study sites were determined through conversations and email communications with DNR staff. Potential study sites were those that may have one or more acres of grassland habitat that is open enough to support monarch butterflies. Potential study sites were determined through a combination of satellite imagery, field observation, and communication with DNR staff (often emails to site superintendents). A single DNR property could have up to three sites included in the study.

Once a grassland area was selected as a study site, a random point was placed in the grassland using GIS software. Starting from that random point, 500 meters of transect were run, with specific rules on when and how far to turn when encountering the end of suitable habitat or property lines (see Monarch Joint Venture 2021 for details). Every five meters along the transect, a 0.5m x 2m quadrat (or ‘subplot’ using IMMP terminology) was placed, with a total of 100 quadrats at each site visit. In each quadrat we recorded the blooming species present with open flowers that might have pollen or nectar available to floral visitors. Flowers that were closed due to circadian patterns (e.g., members of the morning glory family, which may close flowers during the hottest part of the day) were recorded as present. Flowers that were not open due to phenology (either too early or too late in the year) were not recorded. Special care was

taken to check flower condition for members of the sunflower family, Asteraceae, that may have showy rays persist even after the last flower has bloomed.

Floral resources at study sites were measured using the IMMP protocol two times in 2020 and three times in 2021 and 2022. The first round of quantitative sampling occurred between 23 May and 14 Jun in 2021 and 2022. In 2020, site visits occurred during this period and the relative number of flowers were estimated for species observed, but quantitative sampling with transects and quadrats did not occur due to travel restrictions associated with the Covid-19 pandemic. The second round of sampling mostly occurred between 28 Jun and 9 Aug, though in 2020 the second round continued until Aug 19 due to pandemic restrictions. The third round of sampling occurred mostly between 17 Aug and 14 Sep, though some sites were sampled later in 2020 (through 25 Sep) and earlier in 2021 (as early as 3 Aug).

The field data collected under Objective 1 allow for the calculation of blooming species diversity and floral abundance for each site visit. The floral abundance is calculated here as the sum of the number of quadrats recorded for all species during a single visit (maximum possible value of 100 quadrats multiplied by the species richness). We measured floral diversity as the inverse of the Simpson's Index, also known as the effective number of types:

$$diversity = \frac{1}{\Sigma p_i^2}$$

where p_i is the proportional abundance of each (i-th) species. Proportional abundance was measured as the number of quadrats a given species was observed in divided by the sum of the number of quadrats for all species during the site visit, that is,

$$p_i = \frac{q_i}{\sum_{j=1}^{R} q_j}$$

where q_i is the number of quadrats for the given (i-th) species, and q_j represents the number of quadrats for each species up through R, the species richness for the site visit.

All values for abundance and diversity were calculated for a single site visit, that is, they were not based on data aggregated across visits within or between years. Separate statistical tests were conducted for the three different rounds of visits (early, middle, or late growing season) in order to highlight seasonal differences between habitat types. We used linear mixed-effects models with measures of abundance or diversity as the response variable, and all response variables log-transformed to satisfy model assumptions. All models included the random effects of study site and DNR property, with the former being nested within the latter. We tested the following potential explanatory variable as fixed effects: a) site type, which was broken down into one of three categories (remnant, restoration, hay/old field), b) latitude, measured in decimal degrees and the WGS84 datum/ellipsoid, c) longitude, in decimal degrees and WGS84 datum, d) whether the site was burned recently (within 10-15 years), e) whether the site was mowed recently, f) whether the site recently had invasive or woody species removal (e.g. herbicide application), g) whether the site had seeding done at any time, and h) year of sampling, which was included as a categorical variable. For burning, mowing, invasive/woody control, and seeding, sites were put into one of three categories: yes, no, unknown. Each explanatory variable of interest was evaluated as a fixed effect separately from the other explanatory variables because there were associations between variables (e.g., remnants tended to have higher latitudes, restorations were burned more often than hay/old fields). Model selection using the Akaike information criterion adjusted for small sample sizes (AICc) was used to compare each model to a null model without the fixed effect.

Data from the Critical Trends Assessment Program (Objective 1b)

We used data from the Critical Trends Assessment Program to assess trends in the abundance of floral resources over 25 field seasons (1997 to 2021) at randomly selected points across Illinois. One aspect of CTAP data collection includes the cover of individual vascular plant species in quadrats (Carroll et al. 2022), and we used these covers for our analyses. Study sites fall into three habitat categories, forests, wetlands, and grasslands. Study sites are

selected by utilizing remotely sensed data and stratified random sampling design (stratified by township). When possible, sites are revisited every five years, meaning that some sites in the data set have five visits across 20 years. Data used for our analysis of the CTAP data excluded sites that were only visited one time.

We took all the species encountered in the CTAP data set in this period and attempted to determine broad guilds of floral visitors associated with those species. We excluded plant species that do not offer rewards to pollinators, largely wind-pollinated species. We used a combination of resources to identify floral visitors, relying heavily on the references collected on the Illinois Wildflowers webpage (Hilty 2019) and Wilhelm and Rericha (2017). In the original proposal we suggested conducting analyses on three possible insect guilds: bees, butterflies, and moths. However, records of floral visitation by moths were largely lacking, including for some species that appear to be adapted for moth pollination. Thus, we grouped butterflies, moths, and skippers into a single category: lepidopterans. We added a third category, beetles, for which plentiful floral visitation data are available.

Trends in floral resources were assessed by summing the coverage of the plant species associated with an insect guild (bees, lepidopterans, or beetles) for each visit to a study site (with 2-5 visits per site). The cover for each guild was divided by the total cover of plants found during the site visit to obtain the proportion of plants attractive to each guild. We then used a mixed-effects model to test the trend in the proportion of cover attractive to each guild through time. The response variable in the models was the proportion of plants attractive to the guild, but in some cases the proportion had to be log-transformed (after adding 0.01, or 1%) to meet model assumptions regarding normality of residuals. The mixed-effects model was constructed with site as a random effect (intercept only). We used model selection with AICc to compare models with CTAP cycle as a fixed effect to null models with no fixed effect. The CTAP cycle refers to different five-year periods across which repeat visits can occur, where 1997-2001 is

cycle 1, 2002-2006 is cycle 2, 2007-2011 is cycle 3, 2012-2016 is cycle 4, and 2017-2021 is cycle 5.

Objective 2 - Quantify milkweed densities

Milkweed densities were estimated using the IMMP protocol, Activity 1, Option A. Data collection along the transect established for Activity 1 allows for floral resource measurements and milkweed abundance measurements. Thus, milkweed density was estimated at the same time and at the same sites described for Objective 1. All observations of milkweeds were separated by species. All members of the subfamily Asclepiadoideae were included in the counts. In our observations, the subfamily was represented by members of the genus *Asclepias* and *Cynanchum*.

Milkweed stems were counted within one meter of the 500-meter long transect line. The result was milkweed counts over a 1000 m^2 area (500m transect x 2m width). However, when there are a large number of milkweeds, the IMMP protocol stated that counts could stop in between quadrats after 100 or 200 stems of a given species were found (the protocol has changed from year to year, thus two numbers are given here). Although counts in between transects could cease, counts within quadrats were to continue in all quadrats no matter how many milkweeds were found. In 2020, we did not record the distance traveled along the transect when reaching 100 milkweeds. The distance was recorded in 2021 and 2022. As a result, in 2020 the estimate of the abundance of milkweeds at sites with a large number of milkweeds relies on the milkweeds found in the 100 quadrats, which covers an area one-tenth the size of the entire transect. In 2021 and 2022 (and at 2020 sites with relatively few milkweeds), milkweed estimates were derived from the entire transect, including spaces in between quadrats.

A single estimate of milkweed density (separated by species) was derived for each study site by taking the mean density value across all site visits. Of our 49 study sites, 44 sites were

visited five or more times and 48 sites visited more than once. Only *A. syriaca* and *A. verticillata* were present at enough sites for meaningful statistical tests (all other species were present at six or fewer sites). Different statistical strategies were used for the two species.

Presence of *A. verticillata* was analyzed, but not abundance, because the species was only present at 17 of 49 sites (an analysis of abundance with 32 values of zero was difficult). The presence of the species was analyzed as a binomial response with a generalized linear mixed-effects model. The random effect included a random intercept for DNR property. With the exception of year of sampling (the mean was calculated across years), the fixed effects were largely the same as in the first part of Objective 1: coarse classification of site type, latitude, longitude, burn treatment, mowing treatment, invasive/woody removal treatment, and seeding treatment. The fixed effects were tested in separate models compared to a null model using AICc (as in Objective 1).

Abundance of *A. syriaca* was analyzed with a linear mixed-effects model. Abundance could be modeled because *A. syriaca* was only absent from one site. The response variable was the density of *A. syriaca* per hectare, after log(x+1) transformation. The random and fixed effects were the same as in the statistical tests for *A. verticillata*.

Objective 3 - Quantify monarch butterfly habitat use

Observational study: Neonates (Objective 3a.i)

To measure oviposition at different study sites by monarch butterflies, we used the IMMP protocol's Activity 2 (Monarch Joint Venture 2021). The measurements occurred at the same study sites (Table 2) associated with Objective 2 and in the first portion of Objective 1, and with the same frequency (two to three times per field season). Under this part of the project, we recorded the number of monarch butterfly eggs and larvae on each milkweed encountered. More than 97% of the 25022 milkweeds that were checked for monarch eggs and larvae were included in the measurements for Objective 2 (quantifying milkweed densities), but

measurements for this portion of the study were not constrained to the transect established for Objectives 1 and 2. In general, checks for eggs and larvae stopped after observing 100 milkweeds, with a higher limit established for *A. verticillata* because of how infrequently monarch eggs are found on the species.

While collecting data on monarch eggs and larvae, we also recorded the number of adult monarchs seen during the same site visit. We counted the number of adults seen and recorded what activity they were involved in (e.g., nectaring, flying, mating). Adult observations were taken opportunistically, thus, we may have counted the same individual more than once and we undoubtedly missed some adult monarchs.

Statistical analysis of the oviposition rates relied on calculating the total number of neonates (sum of eggs and larvae) on each *A. syriaca* plant. Species other than *A. syriaca* were excluded from analyses because they did not have enough neonates (*A. verticillata*) or individual plants (all other species) for meaningful statistical analysis. The total number of neonates for each *A. syriaca* plant was modeled as a response variable with Poisson distribution, using a generalized linear mixed-effects model. The random effects included study site and DNR property, with the former being nested within the latter. A series of models with one fixed effect of interest were compared to a similar model without the fixed effect, and the best option was selected through model selection with AICc. The explanatory variables of interest were similar to those in Objectives 1a and 2, and were included as fixed effects with some modification: a) site type with three categories, b) latitude, c) longitude, d) burn history, e) mowing history, f) history of invasive or woody species control, and g) seeding history, h) abundance of blooms recorded under Objective 1, log(x+1)-transformed, i) whether *A. verticillata* was present or not, as recorded during data collection for Objective 2, j) density of all milkweeds other than *A. verticillata* recorded under Objective 2, log(x+1)-transformed (largely driven by *A. syriaca*), j) size of the grassland in which the study took place, measured in hectares, log-transformed (estimated by using satellite imagery), k) the proportion of remotely

sensed landcover pixels within 5 km that were in row-crop agriculture (USDA 2021), l) the proportion of remotely sensed landcover pixels within 5km that were developed to low, medium, or high intensity (USDA 2021). In addition, every model tested included two influential variables that were important for predicting monarch oviposition, l) year (as a categorical variable), and m) day of year (DOY). For explanatory variables of interest, models were constructed with three fixed effects (year, DOY, and the explanatory variable of interest), and were compared to a model that only included year and DOY.

Separate analyses were conducted for each round of sampling. For the first round of sampling (corresponding approximately to June), we did not collect quantitative data for 2020. Additionally, there were so few monarch neonates observed in 2022 (only two during the first round of sampling, across all sites) that meaningful analyses were not possible. Thus, statistical analysis for the first round of sampling only included 2021 data (models did not include a random effect for site since there were no repeat visits to sites, and year was not included as a fixed effect). For the third round of sampling, too few plants with neonates were observed in 2020 and 2022 (13 and 9, respectively, across all sites), so this round also only included analyses with 2021 data. Analyses for the second round of sampling included all years.

Observational study: Adults (Objective 3a.ii)

We also counted adults at study sites while collecting data on Activity 1 and Activity 2 of the IMMP protocol. A value for the number of adults observed was recorded for each site visit. We tested the same hypotheses for adult counts as neonate counts under Objective 3a. Statistical analyses were identical, except that a random intercept for property was not included due to smaller sample sizes and problems with model convergence.

Experimental study

This part of the study involved planting milkweeds at study sites (Table 3) and revisiting them four to six times to check for monarch eggs and larvae. We used two species for this study, *A. incarnata* and *A. tuberosa*. Plants in their second growing season were obtained from

two vendors, Pizzo Native Plant Nursery (Leland, IL) and Southernwood Garden (Alto Pass, IL). When possible, we used plants from Pizzo Native Plant Nursery for more northern study sites and plants from Southernwood Garden for more southern study sites, although all *A. tuberosa* were purchased from the former.

Milkweeds were planted in a variety of habitat types, including prairie restorations, old fields, hay fields, and mowed lawns. Milkweeds were not planted in remnant prairies and those protected as Illinois Nature Preserves (with an accidental exception at site Des Plaines 3, which was removed). Thus, the plantings occurred mostly at the same sites as the work under Objectives 1 and 2, except for four INPC sites, plus an additional 22 lawn sites on the same DNR properties (Table 3). The original proposal mentioned possible plantings in lower-diversity grasslands dominated by cool-season grasslands, which are a common part of the Illinois landscape. However, we learned while conducting this work that this community is not abundant on the DNR properties we studied, and we categorized our sites into one of three categories: hay/old fields, restorations, lawns.

We planted *A. tuberosa* in a patch of four plants, each individual separated by 20cm and typically in a two-by-two square. We planted *A. incarnata* in three different patch sizes: a single plant, four plants separated by 20cm (typically two-by-two square), and 16 plants separated by 20cm in a four-by-four grid. Each patch (three patches of *A. incarnata* and one of *A. tuberosa* at each study site) was separated by at least 25 meters. Plantings occurred in late June, typically June 20 to June 30. Plants were watered immediately after plantings, and during most revisits unless recent rain made it unnecessary.

We attempted to revisit plants every 14 days to check for monarch eggs and larvae, though the gap between revisits was often larger in 2020 due to problems associated with Covid-19. When revisiting plants we recorded the number of monarchs and the number of plants in the patch that were still alive. When the first round of checks occurred, typically in early July, we replaced plants that had died since the original planting. We tried to record the number

of eggs that were damaged, empty, or contained a dead embryo. However, we have our doubts about the reliability of the data, and this may be connected to human error and over- or under-counting damaged eggs (in 2020, 12% of eggs encountered were dead; in 2021 the number was 16%; in 2022 it was 0%). Thus, we feel our data on the number of dead eggs is not reliable, and is not included in analyses.

When analyzing the number of neonates found on milkweed plants, two temporal factors were clearly influential. There were large differences in years, with 2021 having the most neonates. And the number of neonates found was very strongly associated with the day of year that revisits were made, with a peak on August 15th (DOY 227, or 228 in leap years). All analyses included year as a categorical fixed effect, and days from DOY 227 as a continuous fixed effect.

Analyses were conducted by creating generalized linear mixed-effects models with neonates per plant as a Poisson response variable. In all cases there was a random intercept for study site (the random intercept for DNR property was excluded because it did not contribute statistically in cases where models fit, and in some cases it caused models to fail to converge). In all cases, model selection was completed with AICc. Analyses were separated into three groups.

1) We tested for differences between species by creating a generalized linear mixed-effects model with three fixed effects: year (categorical), absolute number of days from DOY 227, and species (two levels, *A. incarnata* or *A. tuberosa*). This analysis included all study sites.

2) We tested for the influence of site characteristics and planting density. In this analysis, *A. tuberosa* was excluded because of the vastly fewer plants and number of neonates per plant. All models included year and days difference from DOY 227. Additionally, we tested the following fixed effects, and all combinations of two-way interactions:

a) Site type, with three categories (hay/old field, restoration, lawn)

b) Number of plants alive in the patch. This variable was highly correlated with the patch size (1, 4, or 16 plants), but found to have greater predictive power in a preliminary analysis

c) Latitude

d) Longitude

e) Proportion of remotely sensed landcover pixels within 5 km that were in row-crop agriculture (USDA 2021)

f) the proportion of remotely sensed landcover pixels within 5km that were developed to low, medium, or high intensity (USDA 2021).

3) Finally, we analyzed the influence of the plant community observed at each site. The plant community data, relating to the blooming species and spontaneously occurring milkweeds, were collected as part of Activity 1A of IMMP sampling (under Objectives 1a and 2). This analysis only included *A. incarnata* plants, and excluded lawn sites (because they did not have floral surveys or quantitative milkweed density counts). All models included year (categorical) and days difference from DOY 227. The fixed effects tested were the

a) Presence/absence of *A. verticillata*

b) Density of all milkweeds other than *A. verticillata*. This was largely driven by *A. syriaca* density ($R^2 > 0.9$). This variable was log(x+1)-transformed.

c) Blooming plant abundance, as measured under Objective 1a. This variable was log(x+1)-transformed.

d) Diversity of blooming plants, as measured under Objective 1a.

e) All fixed effects and interactions carried forward from Step 2 of this sequence. These were the variables that related to site characteristics and planting density.

Results

Objective 1a – Measuring nectar resources at DNR properties

We collected quantitative records of blooming species and their abundances at 49 sites over 243 visits. In total we had over 1700 records. Our findings for each site visit are given in Supplementary Data Set 1. This data set can be used to determine the dominant species at each study site, the abundance (in terms of number of quadrats) for each species encountered, and a partial species list for the site. Metadata for Supplementary Data Set 1 are in Appendix 2. This data set does not include estimates from the first round of visits during June 2022. Because the June 2022 data were not collected quantitatively, they were included in a separate data set. The estimates from June 2020 are included in Supplementary Data Set 2, and metadata are also in Appendix 2.

For measures of blooming species abundance, the standout explanatory variable was whether invasive or woody species removal had occurred at the site. The seven sites that did not have invasive or woody species control efforts had a much lower abundance of blooming species than 29 sites that did have such management, or the 14 sites for which we did not know (Figure 3). In all three rounds of blooming species measurement, the model which included invasive/woody control was greatly favored over the null model in explaining patterns of abundance (ΔAICc > 7, Akaike weight > 0.97 for each round). Plus, invasive/woody control was a better predictor than all other explanatory variables tested (ΔAICc > 6 for each round).

The only other explanatory variable that was associated with blooming species abundance in at least two of the sampling rounds was site type. In the first round of sampling, the abundance of blooms was much greater at remnant sites (Figure 4). However, there was not statistical support for differences among site types in the first round (the null model had more support, Akaike weight = 0.82). This is likely due to the imbalance in the number of sites for each type; there were 19 hay/old fields, 23 restorations, and only four remnants. The pattern of restorations being deficient in pollinator resources is consistent with what others have pointed out about typical grassland restoration seed mixes (e.g., Havens and Vitt 2016), and patterns seen in degrading forests in Illinois (Mola et al. 2021). In the second round of sampling (the

middle of the field season), hay/old fields were found to have lower bloom abundance, and there was statistical support for differences in bloom abundance among site types (ΔAICc = 2.0, Akaike weight = 0.73). In the third round of sampling, hay/old fields again had the lowest bloom abundance, and restorations had the greatest bloom abundance. There was strong statistical support for a difference between site types (ΔAICc = 3.9, Akaike weight = 0.88). The difference between remnants and restorations was largely driven by the extreme abundance of *Solidago canadensis* (Canada goldenrod) in restorations. Without this species, there was almost no difference between remnants and restorations.

Other associations with bloom abundance included a weak negative association with latitude during the first round of sampling (ΔAICc = 0.9, Akaike weight = 0.61), decreased abundance for unmowed sites in the third round of sampling (ΔAICc = 5.1, Akaike weight = 0.93), decreased abundance for unburned sites in the third round of sampling (ΔAICc = 5.0, Akaike weight = 0.92), and decreased abundance in 2021 during the third round of sampling (ΔAICc = 2.2, Akaike weight = 0.75).

When considering predictors of blooming species diversity, site type was important during all three sampling rounds, with shifting patterns across rounds of sampling (Figure 5). Diversity in restorations was strikingly low in early season sampling, and diversity was almost doubled in hay/old fields and remnants (there was strong statistical support for a difference among site types, ΔAICc = 9.0, Akaike weight = 0.99). In the middle round of sampling, restorations had the highest diversity and hay/old fields the lowest (site type as a fixed effect had moderate statistical support during this round, ΔAICc = 0.8, Akaike weight = 0.60). In the last round of sampling, hay/old fields had the lowest diversity and remnants had the greatest diversity (there was statistical support for differences among site types, ΔAICc = 2.8, Akaike weight = 0.80). The large abundance of blooming plants observed in restorations was not matched in diversity, which is consistent with the dominance of *Solidago canadensis* in late-season restorations.

Two other site variables showed differences in categories in two of three rounds of sampling. Sites that had invasive or woody control had greater diversity than sites with no control in the second and third rounds (Figure 6; for the second round of sampling, ΔAICc = 20.0, Akaike weight > 0.99; for the third round of sampling, ΔAICc = 3.2, Akaike weight = 0.83). Also, sites that were burned had greater diversity in the second and third rounds (Figure 7; for the second round of sampling, ΔAICc = 1.0, Akaike weight = 0.62; for the third round of sampling, ΔAICc = 6.9, Akaike weight = 0.97).

If comparing the potential explanatory variables to one another (rather than just the null model), different predictors dominated in each round of sampling. The best predictor during the first round of sampling was site type (ΔAICc = 7.4, Akaike weight = 0.94), during the second round it was invasive and woody control (ΔAICc = 17.6, Akaike weight > 0.99), and during the third round it was burn treatment (ΔAICc = 3.7, Akaike weight = 0.71). Note that these three variables are associated with one another

Objective 1b – Analysis of data from the Critical Trends Assessment Program

We analyzed trends in the abundance of insect-attracting plants across Illinois using CTAP data from 1997 to 2021. Those years represent five complete five-year cycles. Cycles refer to five-year periods during which visits to all sites are attempted, and repeat visits to a site occur in different cycles. Over 1500 plant species were recorded in the CTAP data set during those 25 field seasons. We found evidence in the literature that 759 had floral visitation by either bees (726 plant species), lepidopterans (345 species), or beetles (290 species). A summary of the classifications of species can be found in Supplementary Data Set 3, with metadata in Appendix 2.

In grasslands, trends for insect-attracting plant cover were generally positive. We found evidence for increases in plants that attract bees at a rate of nearly 2% of total plant cover, per five-year cycle (Figure 8; ΔAICc = 17.2, Akaike weight > 0.99). We found increases in the cover

of plants visited by lepidopteran at a rate of approximately 1.5% per five-year cycle (Figure 9; ΔAICc = 18.5, Akaike weight > 0.99). Plants attracting beetles increased in abundance by approximately 1% per five-year cycle (Figure 10; ΔAICc = 7.5, Akaike weight = 0.98; analyses were conducted on log-transformed values of proportion plant cover). The increase in insect-attracting plants in grasslands is consistent with trends found elsewhere in the CTAP data of decreasing cover of introduced species in grasslands. The most common and abundant introduced species in CTAP grasslands are cool-season grasses, such as *Bromus inermis* (Spyreas et al. 2004). We believe the decrease in introduced grass species cover, and increase in the abundance of insect-attracting plants, is related to expansion of and changes to two related practices that occur on Illinois grasslands: prairie restorations and conservation plantings funded by the US Department of Agriculture. r2017).

The trends in floral resources found in wetlands are generally negative, though the trends are not as pronounced as in grasslands. The cover of plants that attract bees is decreasing by over 3% per five-year cycle (Figure 11), with moderate statistical support for the decline (ΔAICc = 2.0, Akaike weight = 0.73). The cover of lepidopteran-plants has decreased by about 0.7% per five-year cycle (Figure 12; ΔAICc = 3.7, Akaike weight = 0.86; analyses were conducted on log-transformed values of proportion plant cover). For beetles, we found a humped pattern, with a peak of beetle-plant abundance during cycles 2 and 3 (Figure 13), but we did find statistical support for an overall decline of ~0.25% per year (ΔAICc = 2.1, Akaike weight = 0.74; analyses were conducted on log-transformed values of proportion plant cover). We believe that the decline in the abundance of floral resources for these three insect groups is tied to the increase in invasive plants in, especially *Phalaris arundinacea*. Other work using CTAP data has shown that wetland invasives have an outsized effect on native competitor abundance (Pearse et al. 2019), and the overall abundance of invasives is increasing in CTAP wetlands.

In forests, it appears as though floral resources are generally declining. We found strong evidence that the abundance of bee-attracting plants is declining, at a rate of about 1% per five-year cycle (Figure 14; ΔAICc = 15.0, Akaike weight > 0.99). A slower decline (0.3% per five-year cycle) was found for plants attracting lepidopterans (Figure 15), with strong statistical support (ΔAICc = 4.9, Akaike weight = 0.92; analyses were conducted on log-transformed values of proportion plant cover). The abundance of forest flowers that attract beetles was stable (Figure 16; support for the model that included the fixed effect was less than that for the null model, Akaike weight = 0.62). The decline we observed in plants that attract bees and butterflies is consistent with the findings of Mola et al. (2021), that found declining bumble bee resources in Illinois forests. Possible causes of that decline include forest degradation, mesophication (Nowacki and Abrams 2008), and over-browsing by deer (Mola et al. 2021).

Objective 2 – Measuring abundance of milkweeds at DNR properties

Nine milkweed species were encountered along transects and in quadrats while conducting quantitative sampling at our study sites (Table 4). The estimated densities and number of sites ranged widely, with *A. syriaca* and *A. verticillata* the main species encountered.

Statistical models for the presence of *A. verticillata* only found an association with two fixed effects, latitude and longitude. The species was more likely to be encountered at more northern sites (Figure 17, Figure 18; ΔAICc = 2.6, Akaike weight = 0.78), and there was weak evidence that it was more often encountered at western sites (Figure 17, Figure 19; ΔAICc = 0.1, Akaike weight = 0.51). Both these patterns fit with the larger distribution of the species as it declines towards the Ohio River valley.

The abundance of *A. syriaca* was greatest in hay/old fields, and least in remnant habitats (Figure 20), and there was statistical support for a difference among site types (ΔAICc = 4.3, Akaike weight = 0.89). Overall, the densities of *A. syriaca* we found were in line with those in a recent publication from Iowa (Kaul and Wilsey 2019). However, the densities in our remnants

are much lower than in a similar number of Iowa remnant prairies. This may be due to the particular edaphic conditions of the remnants that we encountered, which were sand prairies and one dolomite prairie. There was support for only two other fixed effects, latitude and longitude. Northern sites tended to have lower densities of *A. syriaca* (Figure 21, Figure 22; ΔAICc = 2.9, Akaike weight = 0.81). This does not follow our expectations from looking at the species range, which reaches its southern edge near the southernmost point of Illinois. For longitude, the general pattern was that western sites had lower *A. syriaca* densities (Figure 21, Figure 23), but there was weaker statistical support for this relationship (ΔAICc = 0.9, Akaike weight = 0.61).

Among the other seven milkweed species encountered, it was hard to find strong patterns since they occurred at a maximum of five sites. *Cynanchum laeve*, the most weedy species among the remaining group of milkweeds, was found largely in hay/old fields (5 of 16 hay/old fields, 1 of 23 restorations, 0 of 4 remnants). *Asclepias viridiflora*, a conservative species typically found in remnants and often associated with well-drained soils, was only found in two of our remnant prairies. The greatest richness of milkweeds observed was at our southernmost site, Cretaceous Hills State Natural Area (Pope County), with six species. In general, southern sites tended to have greater milkweed species richness, which is expected since three of the species have a more southern distribution (*A. viridis*, *A. hirtella*, *C. laeve*).

Objective 3a.i – Observations of monarch oviposition on established milkweeds

The number of monarch butterfly neonates (eggs and larvae) encountered was heavily influenced by the day of year (Figure 24) and the year of sampling. Of the ten species of milkweed encountered during our surveys, only *A. syriaca* had enough plants with neonates for statistical comparison (Table 5). The first two years of the study were similar overall in the rate at which monarch neonates were encountered, with 4.5% of *A. syriaca* plants in 2020 and 5.0% of plants in 2021 having at least one neonate (similar to numbers typically recorded in the

literature, see Zaya et al. 2017 and references within). However, 2022 was a bad year for monarch reproduction in Illinois, with only 1.2% of *A. syriaca* plants having a neonate.

Latitude was the only explanatory variable that predicted the number of neonates encountered per milkweed plant in every round of sampling. As latitude increased, the number of monarch neonates increased (Figure 25). Latitude was the strongest predictor in the analyses for round one (ΔAICc = 2.4, Akaike weight = 0.77) and round two (ΔAICc = 10.0, Akaike weight > 0.99), and also performed better than the null hypothesis in tests for round three (ΔAICc = 1.9, Akaike weight = 0.72).

Sites with greater densities of milkweeds (other than *A. verticillata*) tended to have fewer neonates per plant (Figure 26), perhaps indicating a saturation effect where there are many milkweeds. Models that included the density of milkweeds (log-transformed) performed better than the null hypothesis in round two (ΔAICc = 6.6, Akaike weight = 0.97), and was the strongest predictor among all explanatory variables in round three (ΔAICc = 9.3, Akaike weight = 0.99). Statistical tests did not find a relationship between neonates and milkweed densities in round one of site sampling (null model performed better, ΔAICc = 1.6), but the observed pattern suggests that there might be a trend if more than one year of data were analyzed (Figure 26).

Note that earlier we described a relationship between the density of common milkweed and latitude (Figure 21, Figure 22, see Objective 2). The result means that it is difficult to determine if both latitude and milkweed density are contributing to patterns of monarch laying, or if one serves as a confounding variable. However, if eliminating sites south of 39°N, the relationship between latitude and milkweed density disappears. For sites north of 39°N, the abundance of monarch neonates is still predicted by latitude (ΔAICc = 2.0, Akaike weight = 0.73) and the density of milkweeds (ΔAICc = 2.7, Akaike weight = 0.80).

Statistical tests found relationships between neonates per milkweed and the abundance of blooming plants during rounds one and two of sampling. However, the direction of the relationship changes between the two rounds and disappears during the third round, the

strength of the pattern is unconvincing (Figure 27), and the statistical support is relatively weak (ΔAICc < 1.3, Akaike weight < 0.65).

Model selection favored a difference in the abundance of neonates among different seeding treatments, where sites with unknown seeding history had fewer neonates per milkweed. However, the statistical support was very weak (ΔAICc < 0.3, Akaike weight < 0.53), and sites with known seeding treatment (seeded or unseeded) had similar numbers of neonates per plant.

No other variables showed a relationship with neonates per plant in at least two of the three sampling rounds. Interestingly, the landcover variables we tested (agricultural and developed land cover, within 5km, 1km, or 200m) never had a substantial relationship with the number of neonates observed.

Objective 3a.ii – Adult monarch observations

The number of adults observed varied widely across rounds of sampling, with the fewest adults in sampling round 1. The differences among years were not as pronounced as that observed for neonates (Figure 28).

The number of adults observed was associated with different variables in the different sampling rounds. The most influential explanatory variable in the first sampling round was blooming species diversity (ΔAICc = 4.2, Akaike weight = 0.89). Diversity of blooming species was also associated with the number of adults observed in the third sampling round. In both rounds, there was a positive relationship with the number of adults observed (Figure 29).

The most influential explanatory variable in the second sampling round was the presence of *A. verticillata*, although it only had moderate statistical support (ΔAICc = 1.2, Akaike weight = 0.64). Sites with *A. verticillata* had greater numbers of adults in all rounds (Figure 30), but a difference was only statistically supported in the second round. Interestingly, there was a pattern of remnant prairie sites having more adults, especially in the second round (more than 7

adults per visit for remnants, and less than 2.5 adults per visit for the other two habitat types), but the model with site type was not favored over the null. There may be a connection between the abundance of adults observed at remnants, and their high blooming diversity and *A. verticillata* density (Table 4).

The abundance of blooming plants, log(*x*+1)-transformed, was generally positively associated with adults observed (Figure 31). The relationship was only statistically supported during the third round, when it was the most influential explanatory variable (ΔAICc = 8.2, Akaike weight = 0.98).

Three other explanatory variables were statistically supported as fixed effects in at least two of three sampling rounds. The density of milkweeds other than *A. verticillata* (log(*x*+1)-transformed) was positively associated with adult abundance in rounds 1 and 2 (Figure 32). However, statistical support was weak (ΔAICc < 0.6, Akaike weight < 0.58). The amount of landcover classified as developed (low, medium, or high intensity) was negatively associated with the number of adult monarchs observed (Figure 33), and this relationship was strongest in round 1 (ΔAICc = 2.0, Akaike weight = 0.73) and round 3 (ΔAICc = 4.4, Akaike weight = 0.90). Relationships with longitude were weakly statistically supported in rounds 2 and 3, but the signal was weak (ΔAICc < 0.8, Akaike weight < 0.6) and no clear pattern was evident (data not shown).

The overall picture from our monarch adult observations suggest that blooming species are especially important early and late in the season (after and before migration), and milkweed abundance is important in the early and middle parts of the season when the most reproduction is occurring. Also, there are signs that fewer adults are found in areas with greater human development.

Objective 3b – Monarch oviposition on experimentally planted milkweeds

There were vast differences between *A. incarnata* and *A. tuberosa* in terms of the number of neonates observed. The differences held up across site types (data not shown), although the difference was much smaller in 2022 compared to the other two years (Figure 34). Statistical support for a difference between species was unequivocal (ΔAICc = 91.0, Akaike weight > 0.99). If an interaction between species and year was tested, it would likely be supported. The biological basis of this interaction is unknown, but we suspect it is related to plant condition in the different years. In particular, the plantings in 2021 were especially successful because much of the state experienced substantial rains soon after transplanting. As a result, transplanted plants had higher survival and were in better condition. Since *A. tuberosa* is more drought tolerant, this may have been especially helpful to *A. incarnata*. Interestingly, the strongest variable predicting the number of neonates per spontaneously occurring milkweed (Objective 3a) was latitude, but the variable was not important when looking at planted milkweeds. The overall preference for *A. incarnata* is consistent with previous research (Pocius et al. 2018). Previous publications on the degree of preference for *A. tuberosa* for monarch oviposition were relatively sparse (Zaya et al. 2017), and our findings provide greater parameterization for the species.

In the next analysis step, we only investigated at the number of neonates on *A. incarnata* individuals, excluding *A. tuberosa* because of a low number of neonates. We found that there was statistical support for an interaction between site type and size of the planting (ΔAICc = 56.1, Akaike weight > 0.99). No other variables that we tested (latitude, longitude, two variables for surrounding land cover) had substantial predictive power after accounting for year, day of year, and the site type-patch size interaction. Interestingly, more monarch neonates were found on larger plantings in the (semi-)natural grassland types, ‘hay/old fields’ and ‘restorations’. However, in lawns, monarchs preferred to lay eggs on individuals in smaller plantings (Figure 35). We suspect that this is largely due to increased ‘visibility’ of larger milkweed patches in natural grasslands (Grant et al. 2018, Pitman et al. 2018). However, in lawns milkweeds are

already highly ‘visible’ because the immediately surrounding vegetation is more homogenous and less obstructive (Baker and Pitman 2019), thus monarchs could be avoiding high-density patches that may be associated with greater disease, predation, or competition (Pleasants and Oberhauser 2013). It is somewhat surprising that the single isolated *A. incarnata* individuals had the largest number of neonates per plant in lawns, considering that monarchs may survive best on *A. syriaca* that grow in patches of three or more (Fisher et al. 2020).

The last step of analysis only considered ‘hay/old field’ and ‘restoration’ sites that had floral surveys conducted using Activity 1 of the IMMP protocol. These surveys estimated the abundance and diversity of blooming plants (see Objective 1a) and the density of various milkweed species (see Objective 2). We found that sites with greater floral abundance had greater numbers of neonates per plant (Figure 36), and that there was strong statistical support for a model that included this explanatory variable and the size of the planting (ΔAICc = 15.7, Akaike weight > 0.99 when compared to all other models). We further tested for an interaction between blooming plant density and milkweed patch size, but the more parsimonious model that only included main effects was favored (ΔAICc = 1.5, Akaike weight = 0.68). All other explanatory variables did not have strong predictive power, including site type, which was so important in Step 2. After incorporating the abundance of flowers and removing ‘lawn’ sites, the further categorization of site (‘restoration’ versus ‘hay/old field’) did not have predictive power.

Meeting of Project Objectives and Needs

The broad goals of this work, as stated in the Project Proposal, were to:

a) quantify the extent of resources available to monarch butterflies on public natural areas in Illinois, especially those owned by the Illinois Department of Natural Resources.

b) determine conditions that promote monarch habitat use

Our findings establish what blooming species and milkweeds are present at DNR properties, estimate their abundance, and characterize site characteristics associated with

greater abundances. One finding of our work with practical implications is the confirmation that restored grasslands are lacking in blooming species early in the season and lacking in blooming diversity late in the season.

Among milkweeds, it was no surprise that we identified *A. syriaca* as the most widespread milkweed on DNR property, and the one most used by monarchs for oviposition. *Asclepias verticillata* is another abundant milkweed in DNR grasslands, though the species is almost never utilized for oviposition. Our transplanting experiment provides more evidence that *A. incarnata* is a highly preferred milkweed species for oviposition, and that it is a useful species for experimental manipulations. Meanwhile, *A. tuberosa* is utilized at a lower rate than *A. syriaca* or *A. incarnata*, but at a greater rate than *A. verticillata*.

Our findings suggest that female monarchs are more likely to utilize milkweeds in larger localized patches, but that greater milkweed abundances across the entire grassland may suppress or saturate monarch oviposition. Northern grasslands tend to support more monarch eggs and larvae (per milkweed plant), although some of this relationship may be due to differences in the density of *A. syriaca*. Our results can provide guidance on milkweed plantings that is specific to different habitat types, where concentrated patches of milkweeds may be helpful in grasslands but not in gardens or along lawns. Also, bolstering larval resources north of 40°N should have a greater effect for monarch conservation than further south, while the promotion of nectar resources is valuable across the whole state, especially when extending the scope to other pollinators.

In terms of the specific Objectives from the Project Proposal, the goals for each have been met or exceeded. Some small changes were made to the proposed methods, such as changing the secondary milkweed species used in experimental plantings (from *A. syriaca* to *A. tuberosa*), and shifts in the numbers of sites visited across years. Perhaps the biggest shortcoming was the unavailability of information on management history for some sites.

A big step forward in the future would be to develop and implement a method to efficiently characterize, record, and digitize information on site management. Much of our time and effort was spent trying to find information on site management history, and there was a substantial amount of information still missing for some sites. This is especially important for actions like seeding history, and details on seed mixes used. The information on seeding was often unknown, but it is an important action that can have long-term effects. Currently, much of the information on site management is stored on disparate files (electronic and paper), and in people's memories. A somewhat-centralized, perhaps spatially explicit accounting system would be useful to DNR for a variety of reasons, especially if it is flexible enough to incorporate historical knowledge and future action.

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Table 1. Comparison of the original proposed timeline of actions, and the actual timing of actions.

Dates	Proposed Actions	Actual Actions
Oct 2019 – Jan 2020	Begin planning process, selection of study sites, hire academic hourly employee	Completed on schedule
Feb – Apr 2020	Complete necessary permits, hire seasonal crew members, acquire supplies	Completed on schedule
May – Sep 2020	Begin first field season a) Quantify floral resource abundance at 25-30 sites, each visited 2-3 times during the season b) Quantify milkweed densities at the same 25-30 sites, each visited 2-3 times during the season c) Quantify monarch oviposition rates at the same 25-30 sites, each visited 2-3 times during the season	Completed on schedule. a) Floral resources were measured for 35 sites. Each site was visited three times, one initial visit estimated the quantity of dominant blooming species, and two visit quantified floral resources with transect and quadrat sampling. b) Milkweed densities were quantified at the same 35 sites with two visits. c) Monarch oviposition rates were quantified at the same 35 sites with two visits.
Jun – Jul 2020	Plant nursery-grown milkweeds for experimental study	Completed on schedule. Plantings occurred at 48 sites.
Jul – Sep 2020	Check oviposition rates on experimentally planted milkweeds	Completed on schedule. There were four rounds of checks.
Oct – Dec 2020	Summarize and analyze data, compile additional records, and produce annual report.	Completed largely on schedule, although some compilation did not occur until early 2021.
Jan – Feb 2021	Complete preliminary analyses (mixed-effects models) which may be used for presentations and progress reports	Completed slightly after schedule. At this time mixed-effects models were not fitting the data well.
Jan – Apr 2021	Plan for sampling, complete necessary permits	Completed on schedule

May – Sep 2021	a) Quantify floral resource abundance at 25-30 sites, each visited 2-3 times during the season b) Quantify milkweed densities at the same 25-30 sites, each visited 2-3 times during the season c) Quantify monarch oviposition rates at the same 25-30 sites, each visited 2-3 times during the season	Completed on schedule. All three variables were quantified at 38 sites, each visited and measured three times during the season.
Jun – Jul 2021	Plant nursery-grown milkweeds for experimental study	Completed on schedule. Plantings occurred at 51 sites.
Jul – Sep 2021	Check oviposition rates on experimentally planted milkweeds	Completed on schedule. There were six rounds of checks.
Oct – Dec 2021	Summarize and analyze data, compile additional records, and produce annual report.	Largely completed on schedule, although some compilation and data cleaning was not completed until Mar/Apr 2022.
Jan – Feb 2022	Complete preliminary analyses (mixed-effects models) which may be used for presentations and progress reports	Completed after scheduled, in spring and autumn 2022.
Jan – Apr 2022	Plan for sampling, complete necessary permits	Completed on schedule
May – Sep 2022	Begin final field season a) Quantify floral resource abundance at 25-30 sites, each visited 2-3 times during the season b) Quantify milkweed densities at the same 25-30 sites, each visited 2-3 times during the season c) Quantify monarch oviposition rates at the same 25-30 sites, each visited 2-3 times during the season	Completed on schedule, but at fewer sites than proposed. All three variables were quantified at 21 sites (a twenty-second site was destroyed during the field season and data discarded). Nonetheless, overall project goals were exceeded for data collection in these three categories because we exceeded goals in 2020 and 2021.
Jun – Jul 2022	Plant nursery-grown milkweeds for experimental study	Completed on schedule, with plantings at 30 sites.
Jul – Sep 2022	Check oviposition rates on experimentally planted milkweeds	Completed on schedule, with five rounds of checks.
Sep 2022	Prepare final report	This is the final report.

Table 2. Summary of characteristics and management history for study sites included in floral resource and milkweed abundance estimates (Objectives 1 and 2). Coordinates represent the starting point for the transect associated with Activity 1A in the IMMP protocol. See Appendix for details on each site, including the properties where each is located.

Site	Latitude	Longitude	Description	Coarse Classification	Seeded?	Seed Milkweed?	Burning	Mowing	Invasive or Woody Control (e.g. herbicide)
Argyle 2	40.4709	-90.7985	Old field	Hay/old field	No	No	No	Yes	No
Ayers 1	42.0530	-90.1066	Dry sand prairie remnant	Remnant	No	No	Yes	No	Yes
Bull 2	42.3426	-88.3727	Old field, cool season grassland	Hay/old field	Unknown	Unknown	Unknown	Unknown	Unknown
Coffeen 1	39.1042	-89.4174	Prairie restoration	Restoration	Yes	Yes. *A. tuberosa, A. sullivantii, A. incarnata* 1/2 oz/acre	Yes	Yes, selective	Yes
Crawford 1	39.0990	-87.7003	Old field with woody encroachment	Hay/old field	Unknown	Unknown	Unknown	Unknown	Unknown
Crawford 2	39.0868	-87.7275	Fallow field	Hay/old field	Unknown	Unknown	Unknown	Yes	Unknown
Cretaceous 1	37.2257	-88.5329	Old field with woody encroachment	Hay/old field	No	No	Yes	Yes, near fence and road	Yes
Des Plaines 3	41.3875	-88.2040	High quality dolomite prairie and brome grassland	Remnant	Yes	No	Yes	No	Yes
Des Plaines 4	41.3356	-88.1650	Old field dominated by cool season grasses	Hay/old field	Yes	No	Yes	Yes	Yes
Double T 1	40.5951	-90.1019	Reclaimed strip mine with prairie restoration	Restoration	Yes	No	Yes	Unknown	Yes
Double T 2	40.5966	-90.1095	Reclaimed strip mine with prairie restoration	Restoration	Yes	No	Yes	Unknown	Yes
Double T 4	40.5963	-90.1140	Reclaimed strip mine with prairie restoration	Restoration	Yes	No	Yes	Unknown	Yes
Franklin 2	41.8645	-89.3509	Prairie restoration	Restoration	Yes	Unknown	Yes	Unknown	Yes
Freeman 1	39.4385	-89.6279	Cool season grassland with past restoration efforts	Restoration	Yes	Yes. *A. tuberosa*, ~1-4 oz/acre	Not for ~20 years	Yes	Yes
Freeman 2	39.4355	-89.6367	Cool season grassland with past restoration efforts	Restoration	Yes	Yes. *A. tuberosa*, ~1-4 oz/acre	Not for ~20 years	Yes	Yes

Site	Latitude	Longitude	Description	Coarse Classification	Seeded?	Seed Milkweed?	Burning	Mowing	Invasive or Woody Control (e.g. herbicide)
Fulton 1	41.9183	-90.1152	Remnant sand prairie	Remnant	Yes	Unknown	Unknown	Unknown	Yes
Jim Edgar 2	39.9887	-90.0727	Low diversity grassland	Hay/old field	Unknown	Unknown	Yes	Yes	Yes
Jim Edgar 3	39.9563	-90.0552	Old field	Hay/old field	Unknown	Unknown	Yes	Yes	No
Kishwaukee 1	42.0957	-88.8722	Low diversity grassland	Hay/old field	Unknown	Unknown	Probably no	Yes	Probably no
Mackinaw 1	40.5554	-89.3142	Prairie restoration	Restoration	Unknown	Unknown	Yes	Unknown	Yes
Mackinaw 2	40.1182	-89.3964	Prairie restoration	Restoration	Unknown	Unknown	Yes	Unknown	Yes
Mackinaw 3	40.5554	-89.3142	Prairie restoration	Restoration	Unknown	Unknown	Yes	Unknown	Yes
Madigan 1	40.1182	-89.3964	Old field	Hay/old field	Unknown	Unknown	Yes	Unknown	Yes
Mead 1	40.2665	-91.1799	Restoration that is adjacent to mesic savannah remnant	Restoration	Yes, in 1993	No, but planted 9 *A. meadii* in 2006	Yes	No	Yes
Meredosia 1	39.8565	-90.4662	Remnant hill prairie	Remnant	Unknown	Unknown	Yes	Unknown	Yes
Middle Fork 4	40.2132	-87.7632	Prairie restoration	Restoration	Unknown	Unknown	Yes	Unknown	Unknown
Middle Fork 5	40.2023	-87.7385	Prairie restoration	Restoration	Unknown	Unknown	Yes	Unknown	Unknown
Moraine 1	40.4143	-88.7373	Old field with ~5 years of restoration	Restoration	Yes	Yes	Yes	Unknown	Unknown
Moraine 2	40.4051	-88.7470	Old field with ~5 years of restoration	Restoration	Yes	Yes	Yes	Unknown	Unknown
Moraine 3	40.4051	-88.7470	Old field with ~5 years of restoration	Restoration	Yes	Yes	Yes	Unknown	Unknown
Morrison 2	41.8491	-89.9653	Old field, perhaps with some restoration efforts	Hay/old field	Unknown	Unknown	Unknown	Unknown	Unknown
Pate 1	41.9860	-88.2511	Prairie restoration	Restoration	Yes	No	Yes	Yes	Yes
Pate 2	41.9821	-88.2672	Prairie restoration	Restoration	Yes	Yes. *A. incarnata* (as seed and/or plugs)	Yes (2009)	Yes	Yes
Pyramid 1	37.9762	-89.5118	Reclaimed strip mine	Hay/old field	Unknown	Unknown	No	No	Yes
Pyramid 2	38.0131	-89.5655	Reclaimed strip mine	Hay/old field	Unknown	Unknown	No	No	Yes
Pyramid 4	38.0395	-89.4669	Reclaimed strip mine	Hay/old field	Unknown	Unknown	Yes	No	No, but will be in future

Site	Latitude	Longitude	Description	Coarse Classification	Seeded?	Seed Milkweed?	Burning	Mowing	Invasive or Woody Control (e.g. herbicide)
Sand Ridge 1	40.3969	-89.8748	Grass-dominated sandy old field	Hay/old field	Yes along firelines	Yes. *A. tuberosa*, limited amounts	Not since ~2001	Yes	No
Silver Springs 1	41.6289	-88.5368	Restoration	Restoration	Yes	No	Yes	No	No
Silver Springs 2	41.6307	-88.5191	Old field	Hay/old field	Yes	No	Not for about 20 years	Not recently	Not recently
Snakeden 2	41.0084	-90.0843	Hay field managed for waterfowl	Hay/old field	No	No	No	Yes (3-4 per year)	Unknown
Snakeden 3	41.0245	-90.0832	Hay field, put into soybeans in 2021	Hay/old field	No	No	No	Yes (3-4 per year)	Unknown
Ten Mile 3	38.1538	-88.6206	Old field	Hay/old field	Unknown	Unknown	Unknown	Yes	Unknown
Ten Mile 4	38.2361	-88.7191	Old field	Hay/old field	Unknown	Unknown	Yes	Yes	Yes
Ten Mile 5	38.2138	-88.7893	Old field	Hay/old field	Unknown	Unknown	Unknown	Unknown	Yes
Volo 1	42.3564	-88.2047	Prairie restoration	Restoration	Yes	Unknown	Yes	Not near plot area	Yes
Volo 2	42.3466	-88.1765	Prairie restoration	Restoration	Yes	Unknown	Yes	Not near plot area	Yes
Willow 2	39.7221	-87.6956	Prairie restoration	Restoration	Unknown	Unknown	Unknown	Unknown	Unknown
Wolf 1	39.5017	-88.6824	Prairie restoration with woody encroachment	Restoration	Yes	Yes	Yes	Yes	Yes
Wolf 2	39.4909	-88.6801	Prairie restoration with woody encroachment	Restoration	Yes	Yes	Yes	Yes	Yes
Wolf 3	39.4833	-88.6849	Old field with woody encroachment	Hay/old field	Unknown	Unknown	Unknown	Unknown	Unknown

Table 3. Sites included in the milkweed planting experiment under Objective 3. Coordinates are approximate and represent the mean coordinates of the different patches planted at each site. The years included in the study and the coarse classification of sites are given.

Site name	2020	2021	2022	Latitude	Longitude	Classification
Argyle 2		x	x	40.4601	-90.8006	hay/old field
Argyle lawn		x	x	40.4601	-90.8010	lawn
Bull Valley 2	x		x	42.3426	-88.3732	hay/old field
Bull Valley lawn	x		x	42.3424	-88.3718	lawn
Coffeen 1	x	x		39.1049	-89.4182	restoration
Coffeen lawn	x	x		39.0713	-89.4132	lawn
Crawford 1	x		x	39.0986	-87.6993	hay/old field
Crawford 2	x		x	39.0871	-87.7274	hay/old field
Crawford lawn	x		x	39.0880	-87.7302	lawn
Cretaceous 1		x	x	37.2253	-88.5315	hay/old field
Des Plaines 3		x		41.3878	-88.1998	remnant
Des Plaines 4		x		41.3354	-88.1691	hay/old field
Des Plaines lawn		x		41.3706	-88.2062	lawn
Double T 1	x	x		40.5962	-90.1010	restoration
Double T 2	x	x		40.5962	-90.1113	restoration
Double T 3	x	x		40.5957	-90.1147	restoration
Double T lawn	x	x		40.5900	-90.1003	lawn
Franklin Creek 2		x	x	41.8637	-89.3504	restoration
Franklin lawn		x	x	41.8571	-89.3519	lawn
Freeman 1	x	x		39.4411	-89.6272	restoration
Freeman 2	x	x		39.4357	-89.6364	restoration
Jim Edgar 2		x	x	39.9896	-90.0735	hay/old field
Jim Edgar 3		x	x	39.9561	-90.0562	hay/old field
Jim Edgar lawn		x	x	39.9974	-90.0695	lawn
Kishwaukee 1	x	x		42.0963	-88.8725	hay/old field
Mackinaw 1	x	x		40.5736	-89.3196	restoration
Mackinaw 2	x		x	40.5626	-89.3198	restoration

Site name	2020	2021	2022	Latitude	Longitude	Classification
Mackinaw 3	x	x		40.5542	-89.3149	restoration
Mackinaw lawn	x	x	x	40.5569	-89.3024	lawn
Madigan 1	x		x	40.1188	-89.3952	hay/old field
Madigan lawn	x		x	40.1195	-89.3964	lawn
Middlefork 4	x	x		40.2077	-87.7501	restoration
Middlefork 5	x		x	40.2078	-87.7511	restoration
Middlefork lawn	x	x	x	40.2119	-87.7553	lawn
Moraine 1	x	x		40.4143	-88.7374	restoration
Moraine 2	x	x		40.4049	-88.7470	restoration
Moraine 3	x		x	40.4123	-88.7275	restoration
Moraine lawn	x			40.4123	-88.7243	lawn
Morrison 2	x	x		41.8486	-89.9650	hay/old field
Morrison lawn	x	x		41.8430	-89.9625	lawn
Pate 1	x	x		41.9835	-88.2571	restoration
Pate 2	x	x		41.9839	-88.2599	restoration
Pate lawn		x		41.9781	-88.2576	lawn
Pyramid 1	x	x		37.9762	-89.5129	hay/old field
Pyramid 2	x	x		38.0083	-89.5650	hay/old field
Pyramid 4	x		x	38.0397	-89.4651	hay/old field
Pyramid lawn	x		x	37.9998	-89.4605	lawn
Sand Ridge 1	x	x		40.3965	-89.8749	hay/old field
Sand Ridge lawn	x	x		40.3914	-89.8729	lawn
Silver Springs 1	x	x		41.6292	-88.5369	restoration
Silver Springs 2	x	x		41.6310	-88.5183	hay/old field
Silver Springs lawn		x		41.6287	-88.5199	lawn
Snakeden 2	x	x		41.0079	-90.0834	hay/old field
Snakeden 3	x			41.0250	-90.0830	hay/old field
Snakeden lawn	x	x		41.0192	-90.0748	lawn
Ten Mile 3	x	x		38.1540	-88.6202	hay/old field
Ten Mile 4	x	x		38.2364	-88.7200	hay/old field
Ten Mile 5	x		x	38.2141	-88.7899	hay/old field

Site name	2020	2021	2022	Latitude	Longitude	Classification
Ten Mile lawn			x	38.0821	-88.6259	lawn
Volo Bog 1		x	x	42.3532	-88.2034	restoration
Volo Bog 2		x	x	42.3441	-88.1747	restoration
Volo Bog lawn		x	x	42.3523	-88.1874	lawn
Willow Creek 2		x	x	42.3532	-88.2034	restoration
Willow Creek lawn		x	x	39.7209	-87.6964	lawn
Wolf 1	x	x		39.5013	-88.6809	restoration
Wolf 2	x		x	39.4906	-88.6818	restoration
Wolf 3	x			39.4815	-88.6848	hay/old field
Wolf lawn	x	x	x	39.4842	-88.6850	lawn

Table 4. Summary of estimated milkweed densities at each study site. These data were collected as part of Activity 1A of the IMMP protocol. Estimates were derived from estimates along transects and in quadrats. The majority of sites were visited multiple times with one density estimate per visit, and the values presented here are the means across all visits. See Appendix for details on each site, including the properties where each is located.

	Milkweed density estimates, stems per hectare								
Site name	*A. syriaca*	*A. verticillata*	*A. tuberosa*	*A. viridiflora*	*A. viridis*	*C. laeve*	*A. hirtella*	*A. purpurea*	*A. incarnata*
Argyle 2	45	-	-	-	-	-	-	-	-
Ayers 1	30	7172	-	295	-	-	-	-	-
Bull 2	1392	182	-	-	-	-	-	-	-
Coffeen 1	154	-	-	-	-	-	10	-	-
Crawford 1	807	-	-	-	-	-	-	-	-
Crawford 2	4	-	-	-	-	-	12	-	-
Cretaceous 1	3668	-	22	-	3	3	5	10	-
Des Plaines 3	430	490	-	-	-	-	-	-	-
Des Plaines 4	47	-	-	-	-	-	-	-	-
Double T 1	122	6581	-	-	-	-	-	-	4
Double T 2	112	108	-	-	-	-	-	-	-
Double T 4	94	1396	-	-	-	-	-	-	-
Franklin 2	25	32	-	-	-	-	-	-	-
Freeman 1	394	33840	-	-	-	-	-	-	-
Freeman 2	264	-	-	-	-	-	-	-	-
Fulton 1	-	-	-	40	-	-	-	-	-
Jim Edgar 2	798	3	-	-	-	-	-	-	-
Jim Edgar 3	493	-	-	-	-	-	-	-	-
Kishwaukee 1	220	-	-	-	-	-	-	-	-
Mackinaw 1	20	-	-	-	-	-	-	-	-
Mackinaw 2	645	-	-	-	-	-	-	-	-
Mackinaw 3	340	-	-	-	-	-	-	-	-
Madigan 1	120	18	-	-	-	-	-	-	-

Site name	*A. syriaca*	*A. verticillata*	*A. tuberosa*	*A. viridiflora*	*A. viridis*	*C. laeve*	*A. hirtella*	*A. purpurea*	*A. incarnata*
Mead 1	47	-	-	-	-	-	-	-	-
Meredosia 1	67	4791	-	-	-	-	-	-	-
Middle Fork 4	520	2713	-	-	-	-	-	-	-
Middle Fork 5	56	-	-	-	-	-	-	-	-
Moraine 1	456	-	4	-	-	-	-	-	-
Moraine 2	248	-	50	-	-	-	-	-	-
Moraine 3	102	-	-	-	-	-	-	-	-
Morrison 2	656	-	-	-	-	-	-	-	-
Pate 1	1454	-	-	-	-	-	-	-	-
Pate 2	822	-	-	-	-	-	-	-	2
Pyramid 1	754	-	-	-	6	4	-	-	-
Pyramid 2	548	-	-	-	-	-	-	-	-
Pyramid 4	322	-	-	-	-	4	-	-	-
Sand Ridge 1	258	86610	-	-	-	-	-	-	-
Silver Springs 1	120	-	-	-	-	-	-	-	-
Silver Springs 2	380	1538	-	-	-	-	-	-	-
Snakeden 2	434	104	-	-	-	-	-	-	-
Snakeden 3	540	90	-	-	-	-	-	-	-
Ten Mile 3	1432	-	-	-	-	-	-	-	1725
Ten Mile 4	4126	-	-	-	12	1851	-	-	-
Ten Mile 5	6472	-	-	-	-	76	-	-	-
Volo 1	157	3968	-	-	-	-	-	-	-
Volo 2	180	-	3	-	-	-	-	-	-
Willow 2	398	-	-	-	-	-	-	-	-
Wolf 1	104	-	-	-	-	-	8	-	4
Wolf 2	2796	-	-	-	-	2	-	-	-

Table 5. Summary of overall counts of monarch butterfly neonates from the observational portion of Objective 3. Data were collected using Activity 2 from the IMMP protocol.

Milkweed species	Year	Milkweed stems checked	Neonates per stem	Larvae per stem	Proportion of plants with neonate
A. hirtella	2020	9	0.333	0.333	0.111
	2021	8	0	0	0
	2022	14	0	0	0
A. incarnata	2020	101	0.010	0.010	0.010
	2021	228	0.031	0.009	0.031
A. purpurascens	2021	6	0	0	0
A. sullivantii	2022	10	0	0	0
A. syriaca	2020	2806	0.061	0.007	0.045
	2021	5187	0.063	0.016	0.050
	2022	2108	0.014	0.003	0.012
A. tuberosa	2021	45	0	0	0
	2022	9	0	0	0
A. verticillata	2020	2055	0	0	0
	2021	9723	0.003	0.002	0.003
	2022	2215	0	0	0
A. viridiflora	2022	203	0	0	0
A. viridis	2021	9	0	0	0
	2022	3	0	0	0
C. laeve	2020	90	0.022	0.011	0.022
	2021	141	0.021	0.007	0.021
	2022	40	0	0	0

Figure 1. Map of observational study sites. The plant community and monarch oviposition on existing milkweeds was characterized at these sites with the Integrated Monarch Monitoring Program protocol. All study sites were grasslands on Illinois Department of Natural Resources property.

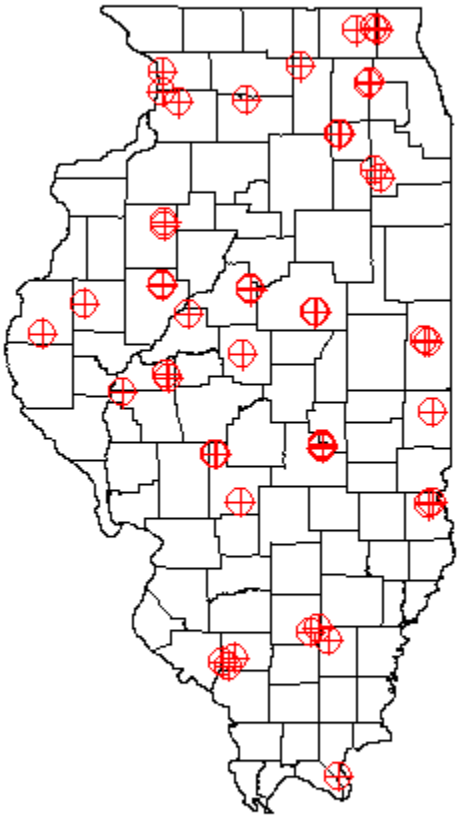


Figure 2. Map of planting sites. Two species of milkweeds were planted at each study site. Transplanted milkweeds were checked for monarch eggs and larvae approximately every two weeks. All study sites were on Illinois Department of Natural Resources property, and represented a mix of grassland and lawns.

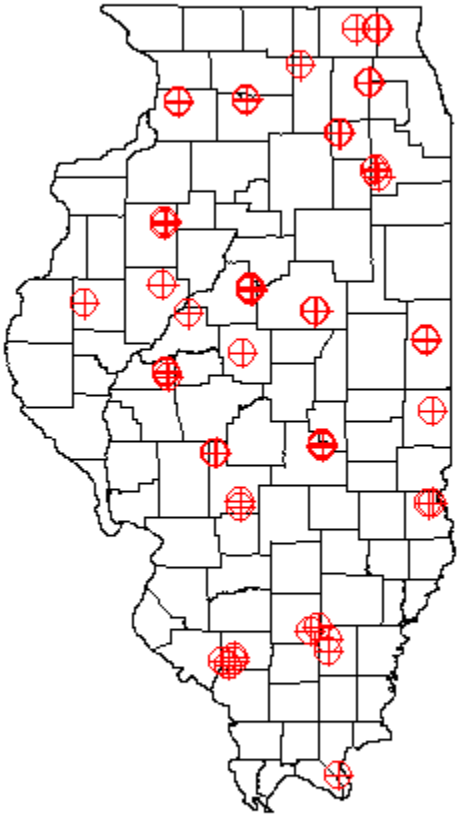


Figure 3. Bloom abundance as a function of invasive or woody species control management, separated by round of sampling. We found that sites differed in the abundance of blooming plants in all three sampling rounds. Analyses were conducted on log-transformed values for bloom abundance, but untransformed values are displayed in this figure. Refer to Table 2 ('Invasive or Woody Control' column) for sample size in each category. Data from the first round do not include 2020.

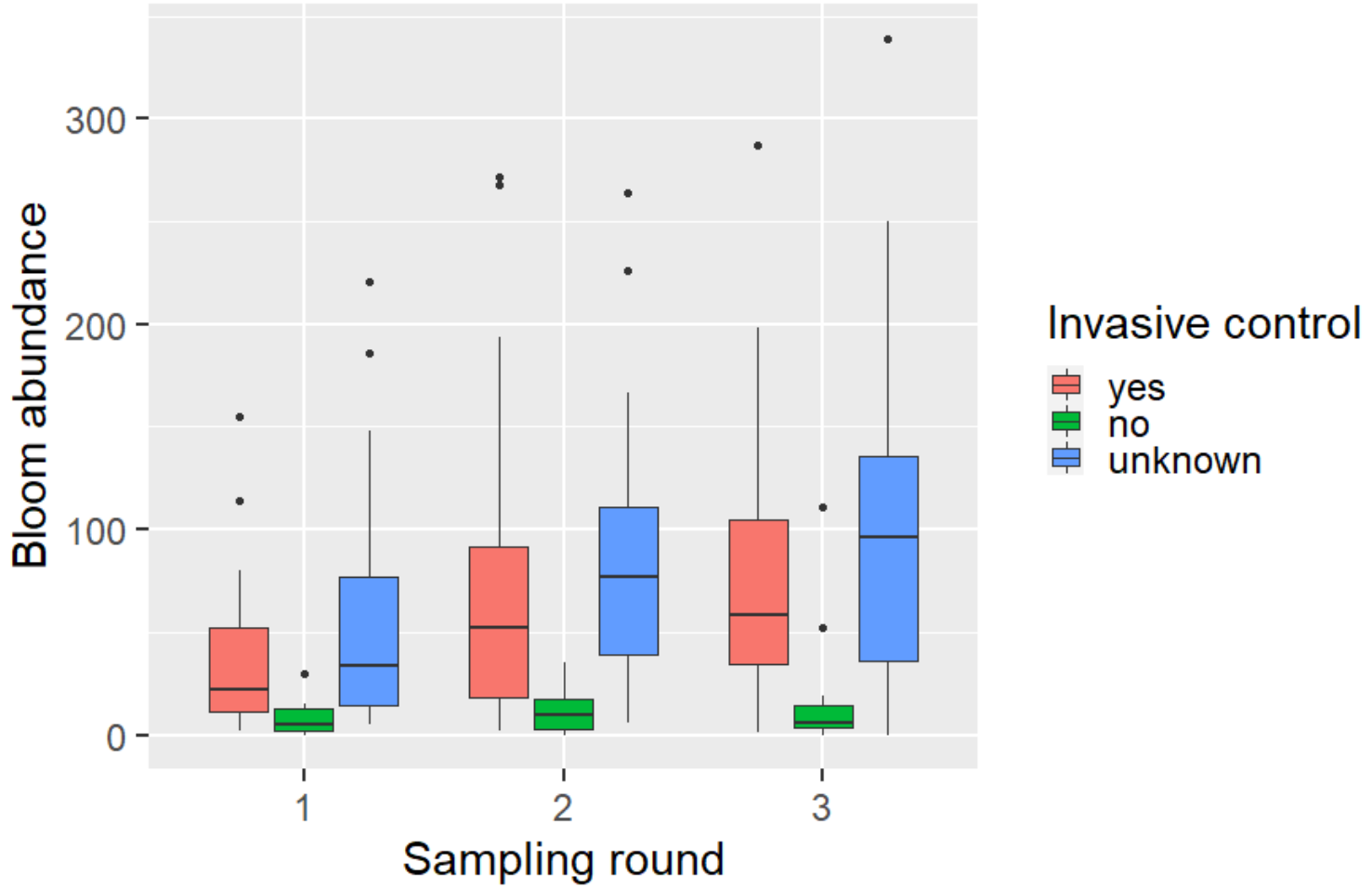


Figure 4. Bloom abundance as a function of site type, separated by round of sampling. We found that the categories differed in the abundance of blooming plants in the second and third sampling rounds. Analyses were conducted on log-transformed values for bloom abundance, but untransformed values are displayed in this figure. Refer to Table 2 ('Coarse Classification' column) for sample size in each category. Data from the first round do not include 2020.

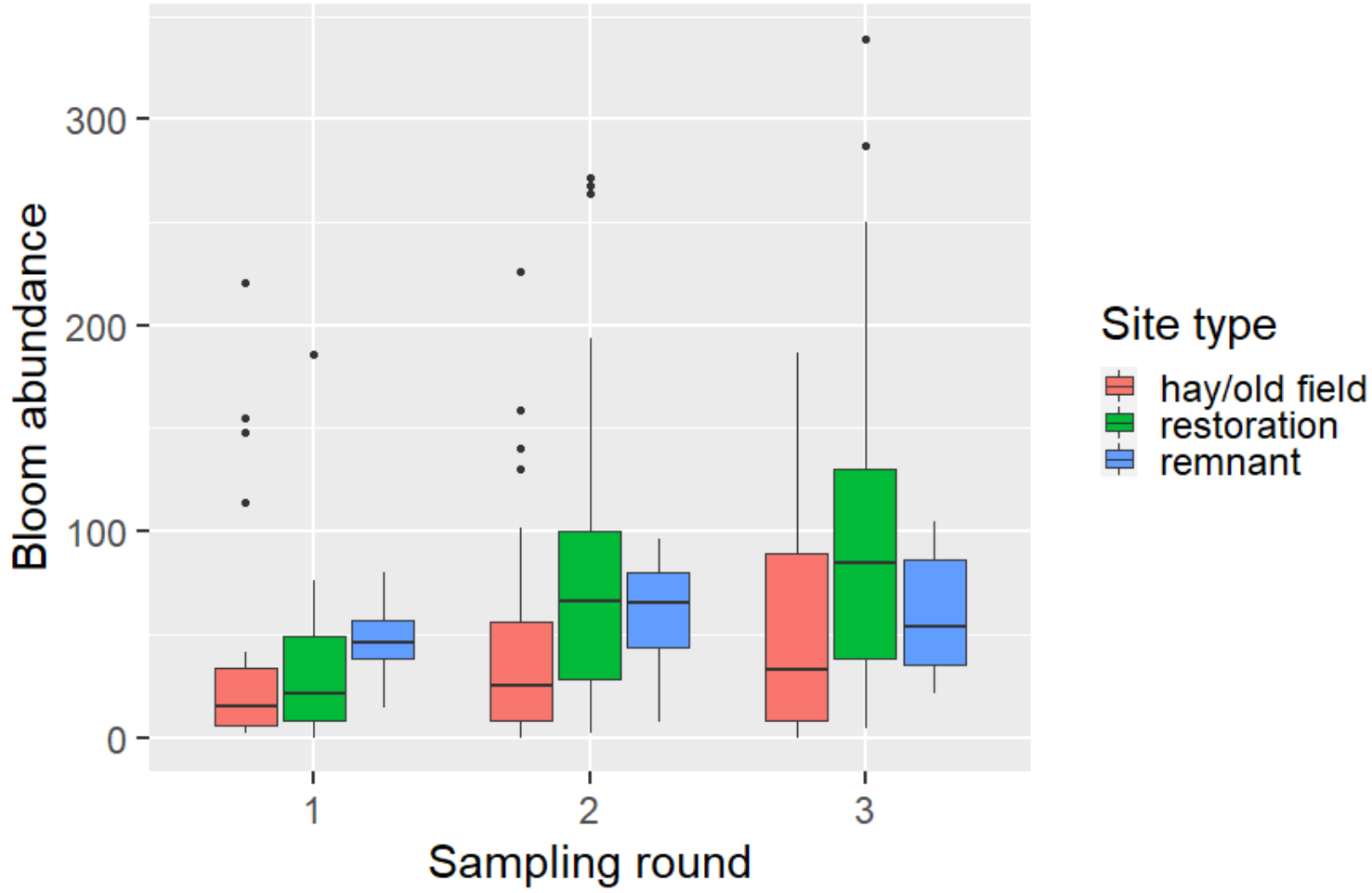


Figure 5. Bloom diversity as a function of site type, separated by round of sampling. We found that the categories differed in the diversity of blooming plants in rounds two and three of sampling. Analyses were conducted on log-transformed values for bloom diversity, but untransformed values are displayed in this figure. Refer to Table 2 ('Invasive or Woody Control' column) for sample size in each site category. Data from the first round do not include 2020. Diversity was calculated as the inverse of the Simpson's Index, see Methods for details.

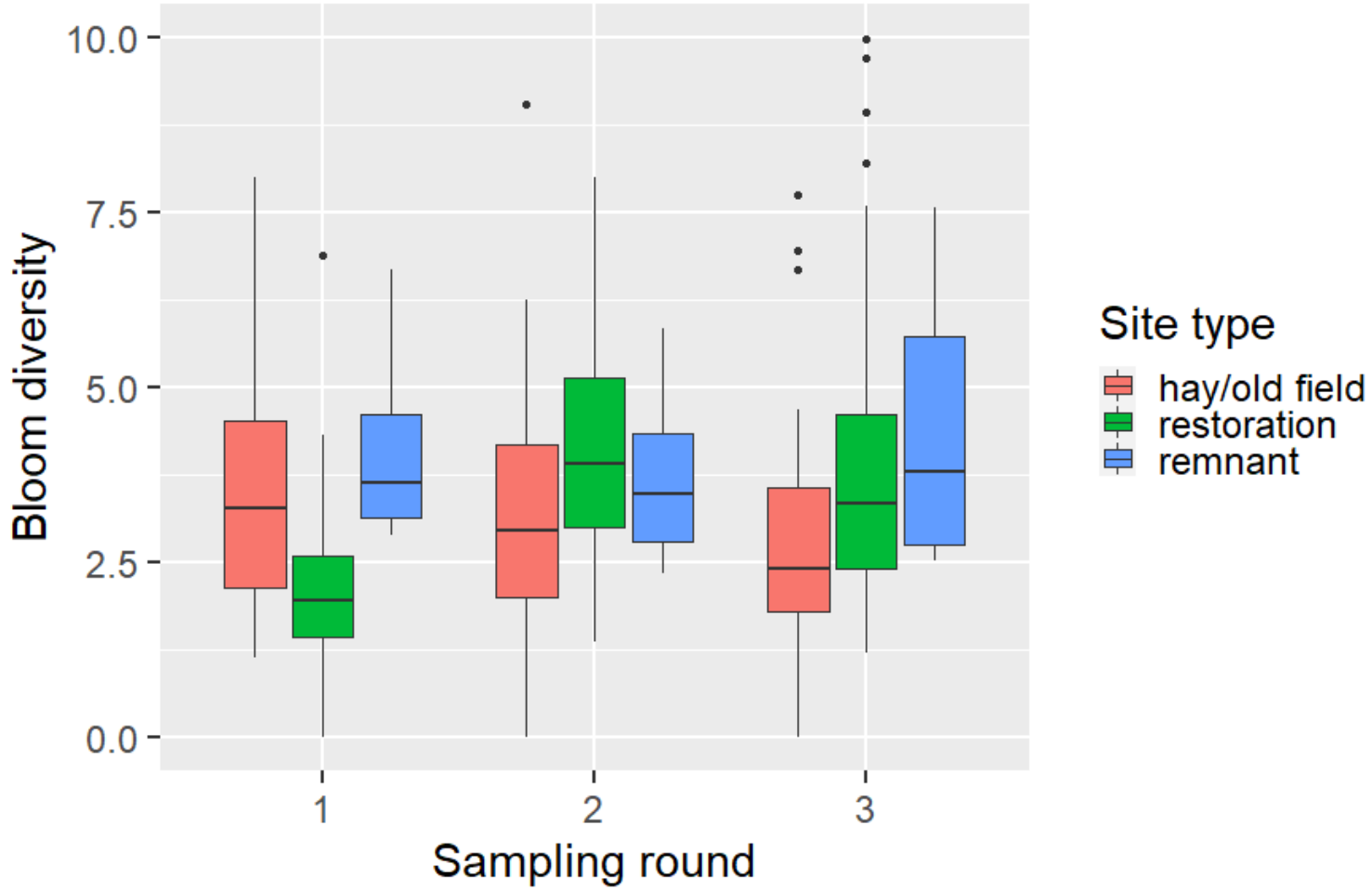


Figure 6. Bloom diversity as a function of invasive or woody species control management, separated by round of sampling. We found that the categories differed in the diversity of blooming plants in the second and third rounds of sampling. Analyses were conducted on log-transformed values for bloom diversity, but untransformed values are displayed in this figure. Refer to Table 2 ('Coarse Classification' column) for sample size in each site category. Data from the first round do not include 2020. Diversity was calculated as the inverse of the Simpson's Index, see Methods for details.

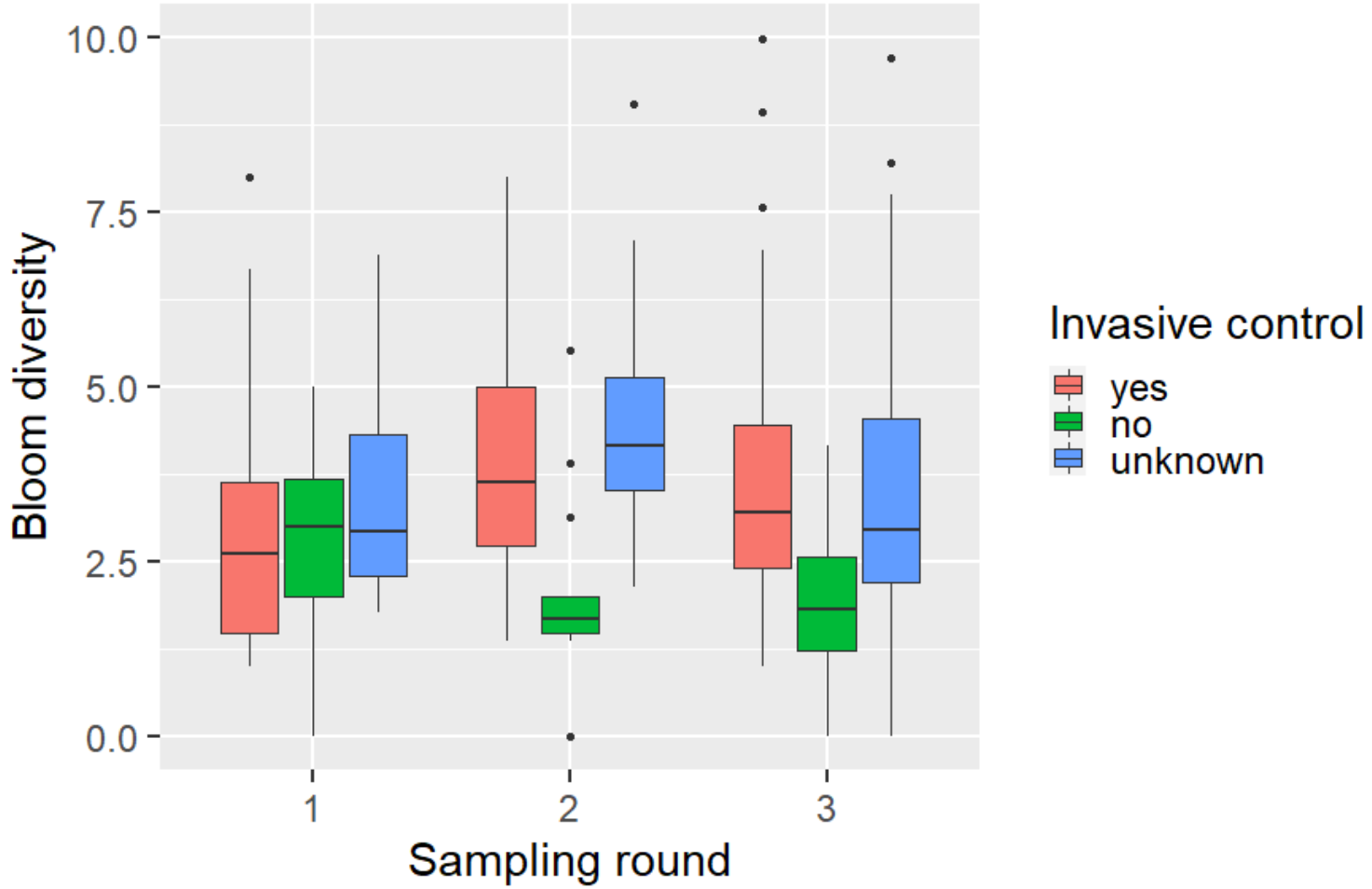


Figure 7. Bloom diversity as a function of recent burning management, separated by round of sampling. We found that the categories differed in the diversity of blooming plants in the second and third of sampling. Analyses were conducted on log-transformed values for bloom diversity, but untransformed values are displayed in this figure. Refer to Table 2 ('Burning' column) for sample size in each site category. Data from the first round do not include 2020. Diversity was calculated as the inverse of the Simpson's Index, see Methods for details.

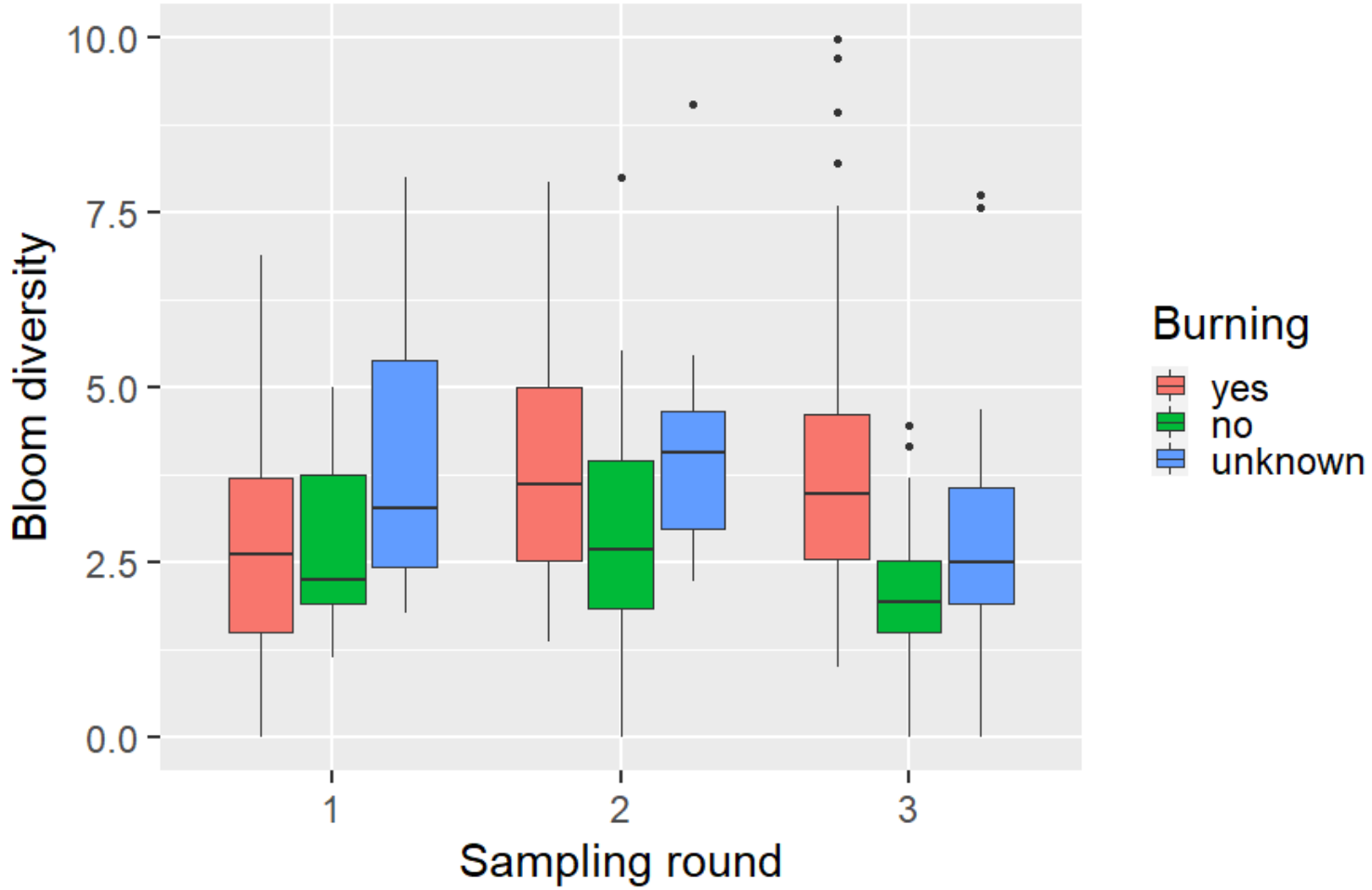


Figure 8. Trends in abundance of plants with flowers that attract bees at CTAP grassland sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. We found statistical support for increase in abundance through time.

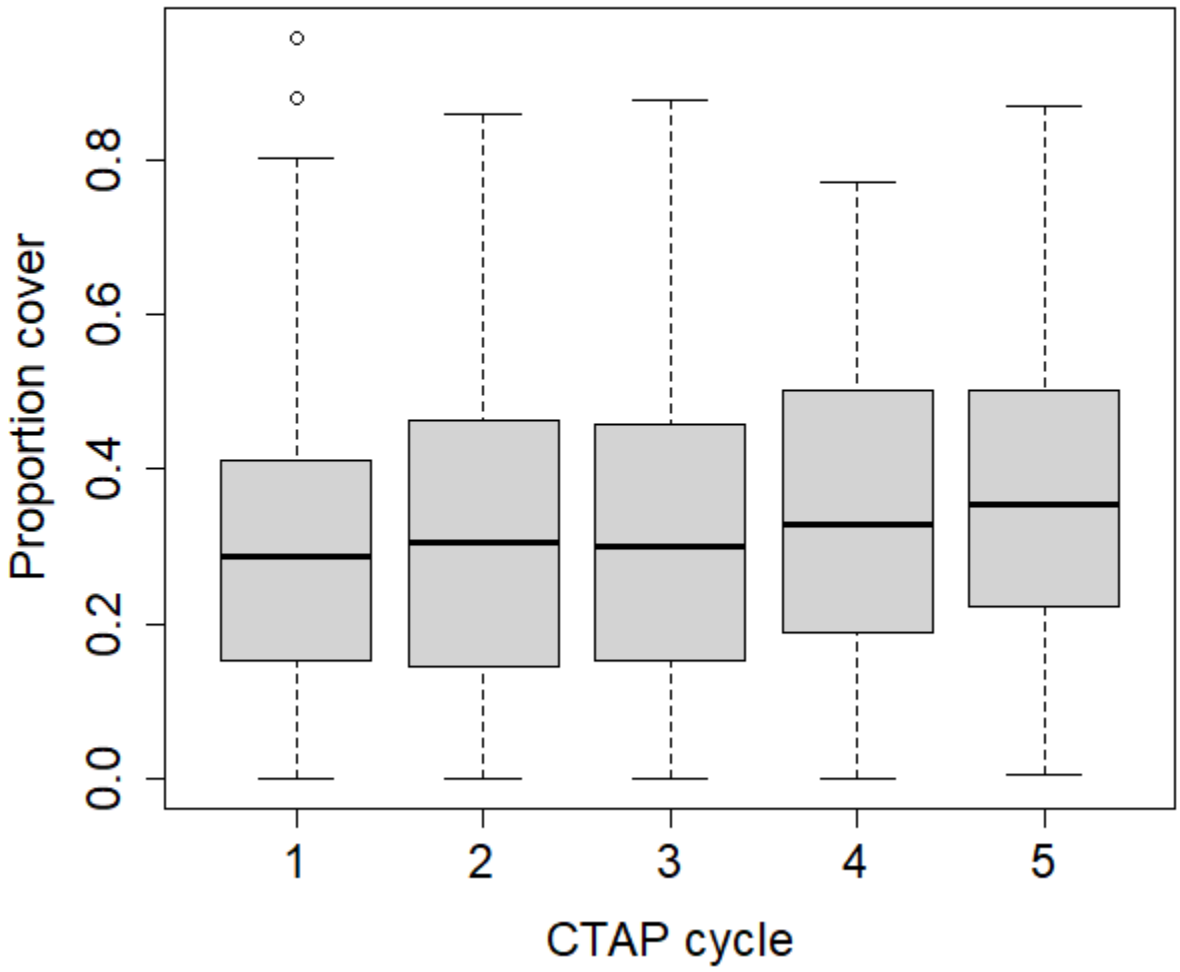


Figure 9. Trends in abundance of plants with flowers that attract lepidopterans at CTAP grassland sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. We found statistical support for an increase in abundance through time.

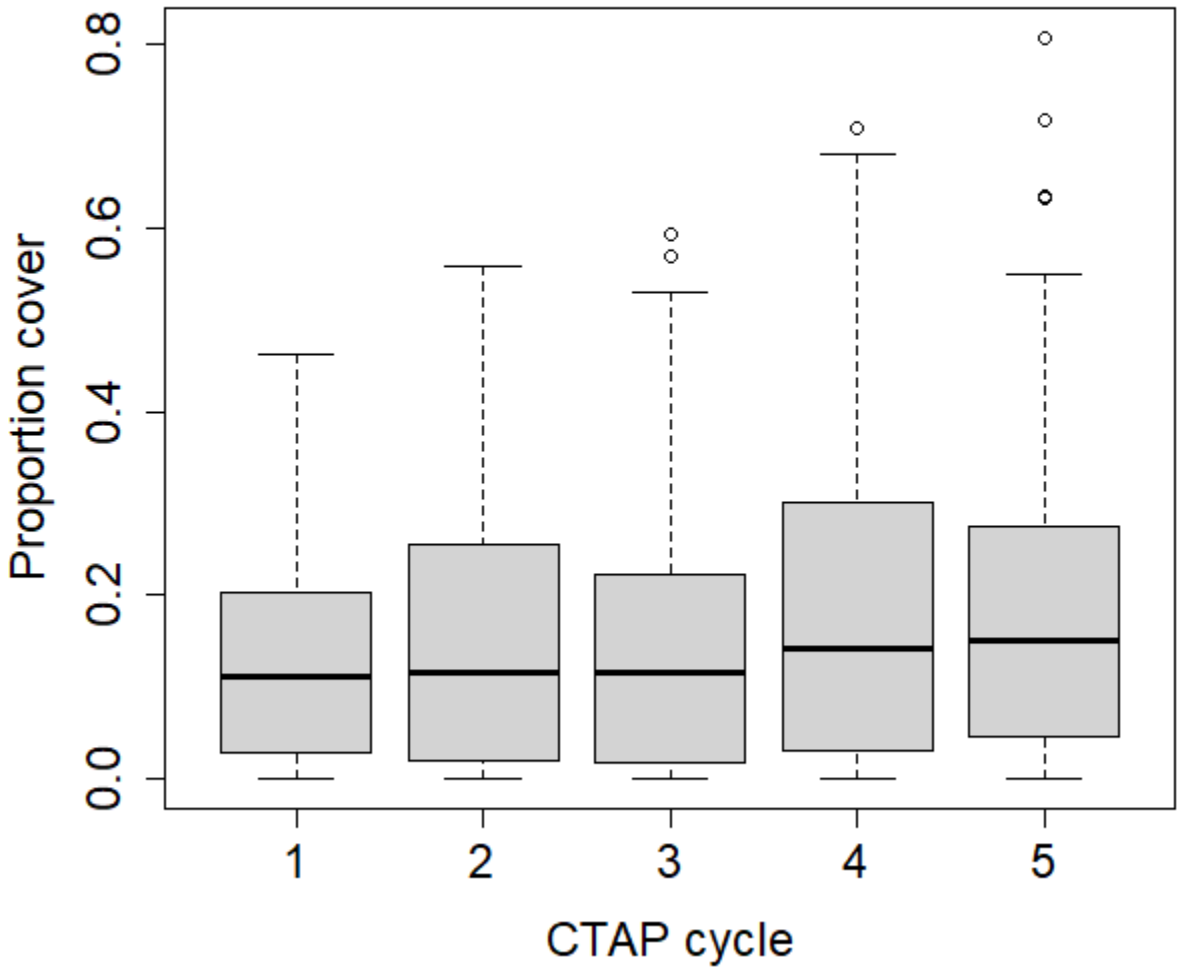


Figure 10. Trends in abundance of plants with flowers that attract beetles at CTAP grassland sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. Analyses were conducted on log-transformed values for plant abundance (specifically proportion cover), but we present untransformed values here. We found statistical support for an increase in abundance through time.

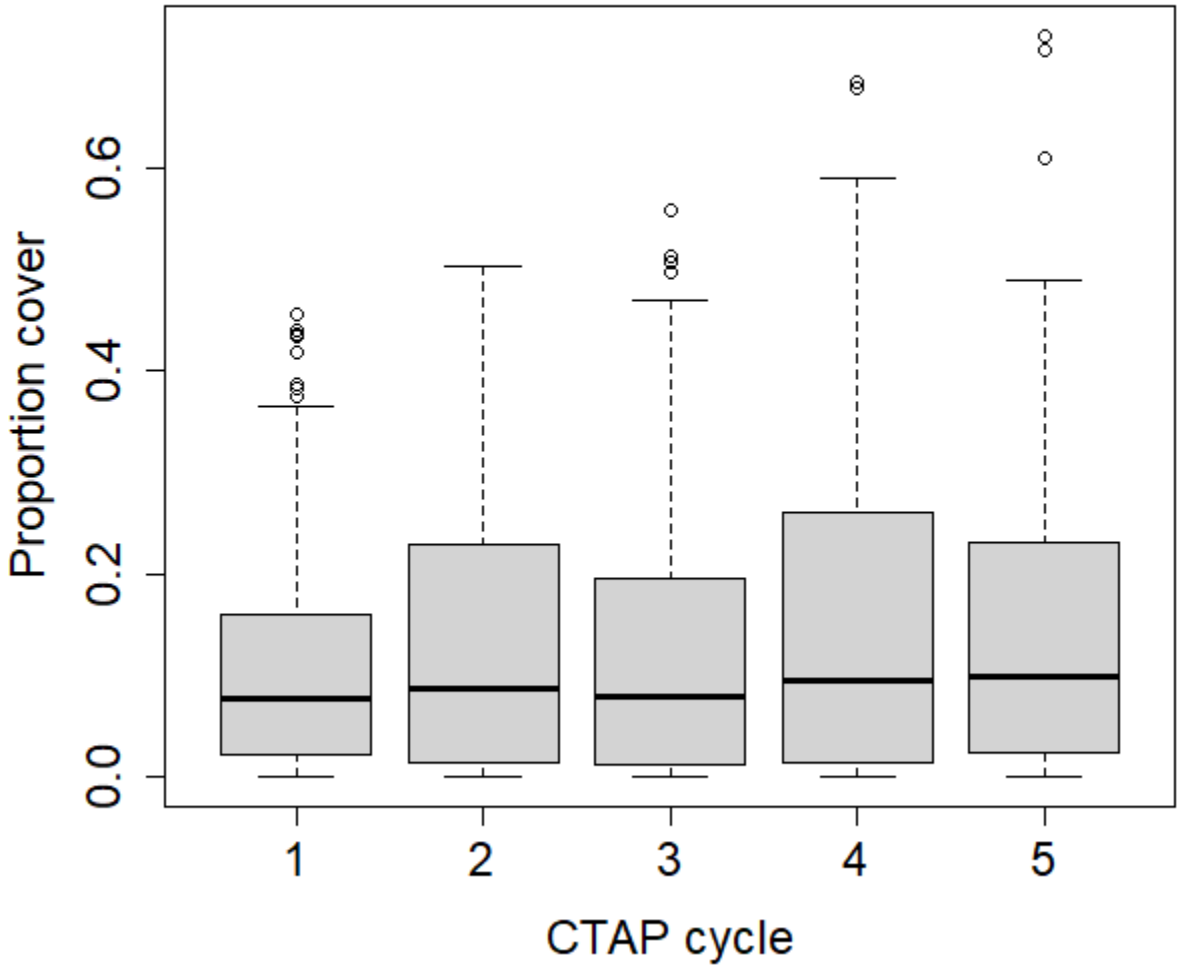


Figure 11. Trends in abundance of plants with flowers that attract bees at CTAP wetland sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. We found statistical support for a decrease in abundance through time.

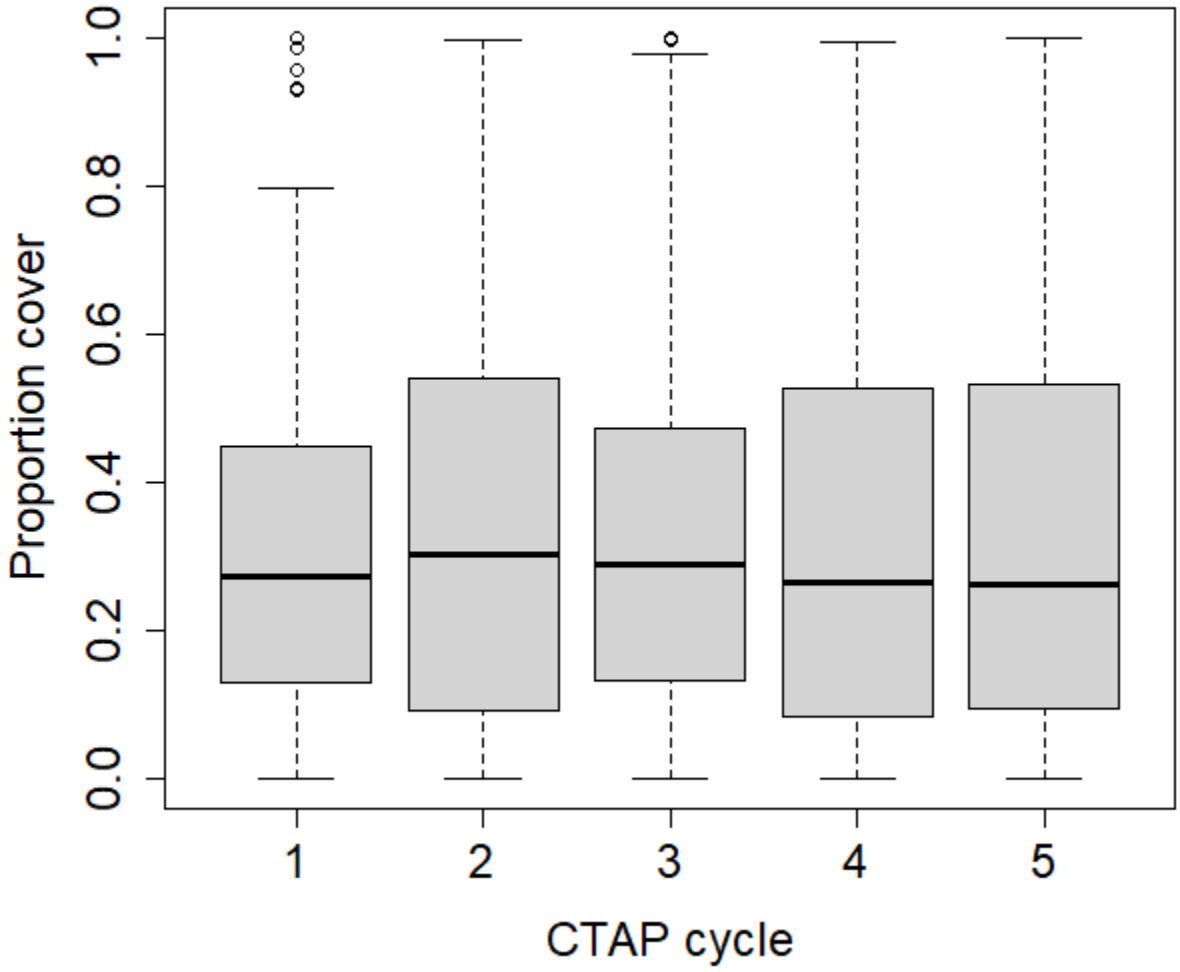


Figure 12. Trends in abundance of plants with flowers that attract lepidopterans at CTAP wetland sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. Analyses were conducted on log-transformed values for plant abundance (specifically proportion cover), but we present untransformed values here. We found statistical support for a decrease in abundance through time.

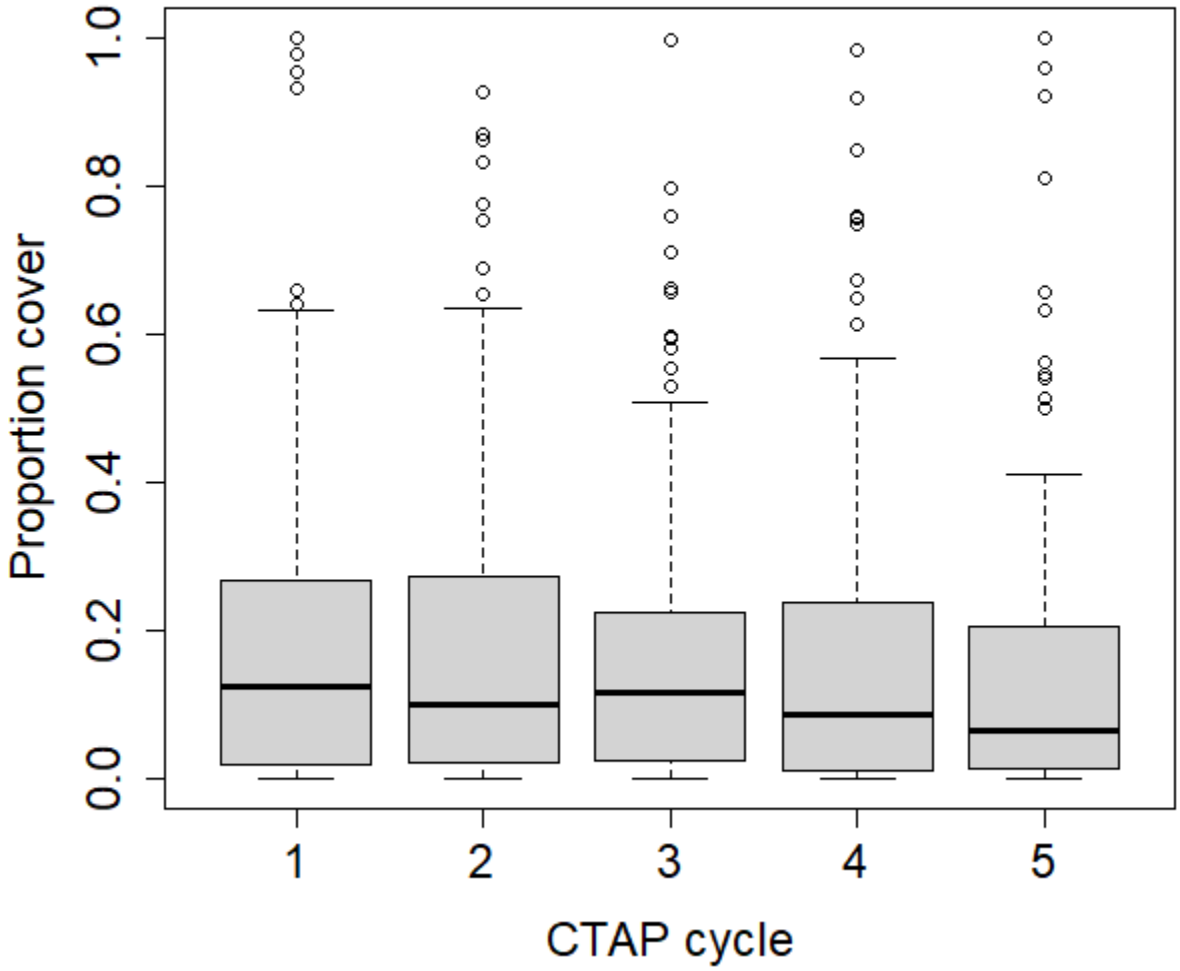


Figure 13. Trends in abundance of plants with flowers that attract beetles at CTAP wetland sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. Analyses were conducted on log-transformed values for plant abundance (specifically proportion cover), but we present untransformed values here. We found moderate statistical support for a decrease in abundance through time.

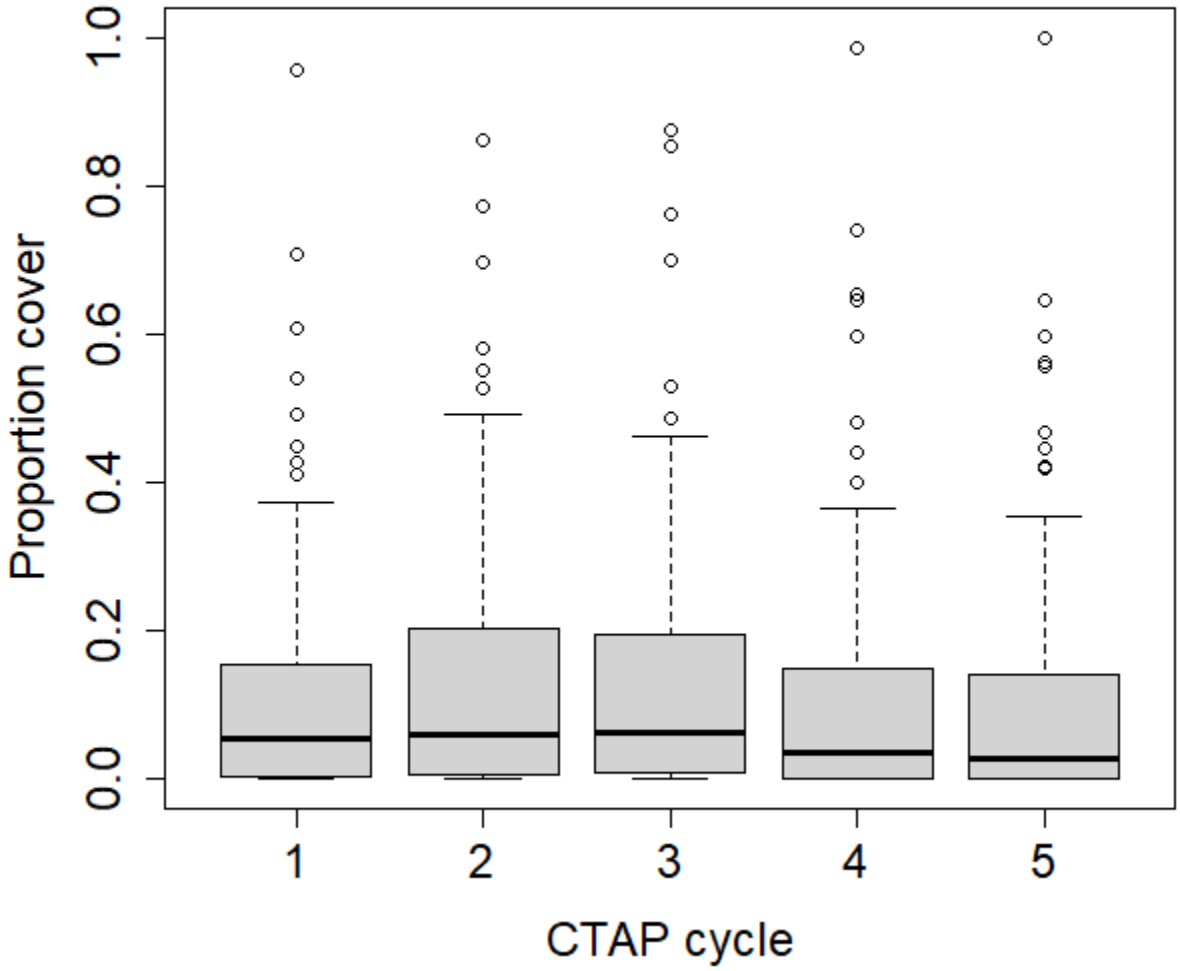


Figure 14. Trends in abundance of plants with flowers that attract bees at CTAP forest sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. We found statistical support for a decrease in abundance through time.

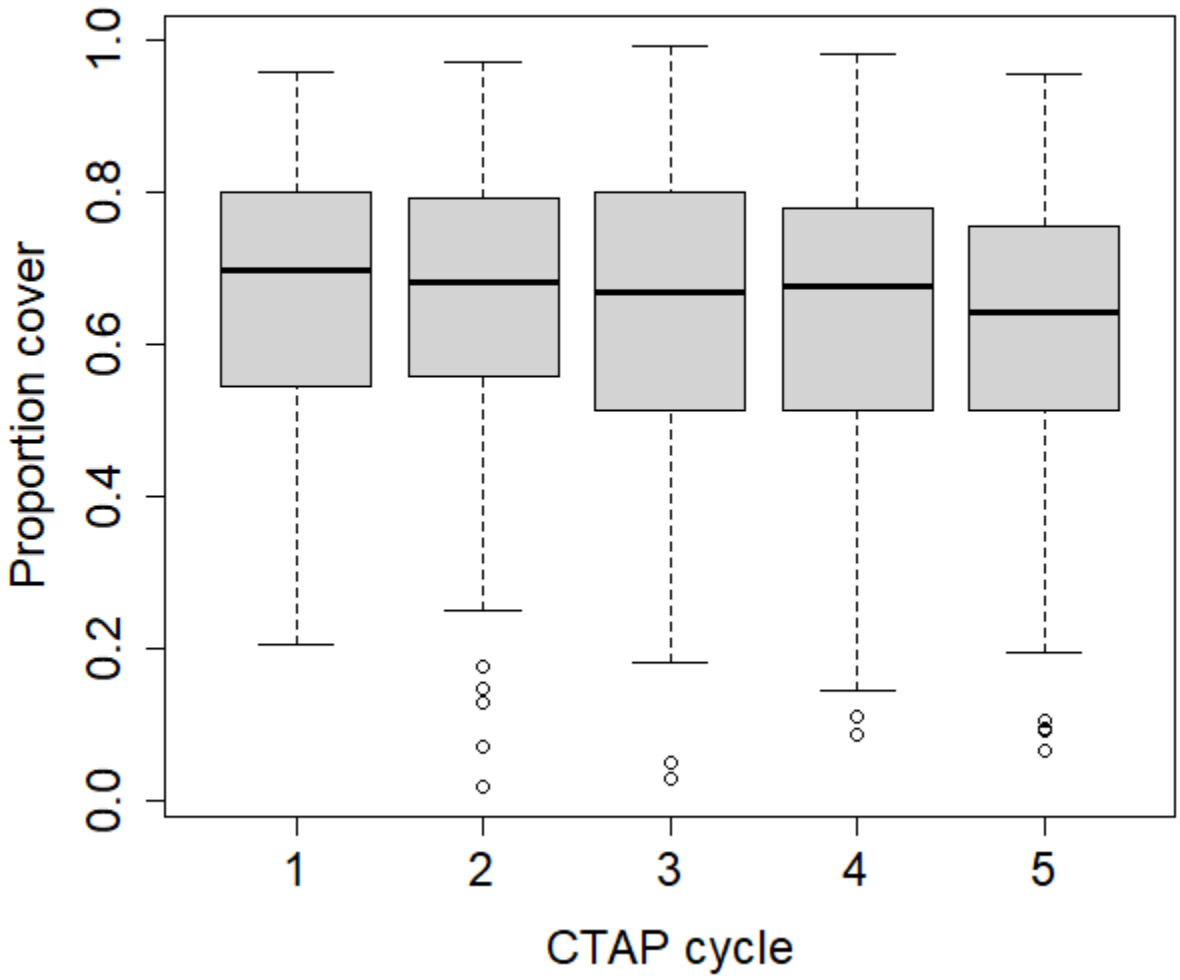


Figure 15. Trends in abundance of plants with flowers that attract lepidopterans at CTAP forest sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. Analyses were conducted on log-transformed values for plant abundance (specifically proportion cover), but we present untransformed values here. We found statistical support for a decrease in abundance through time.

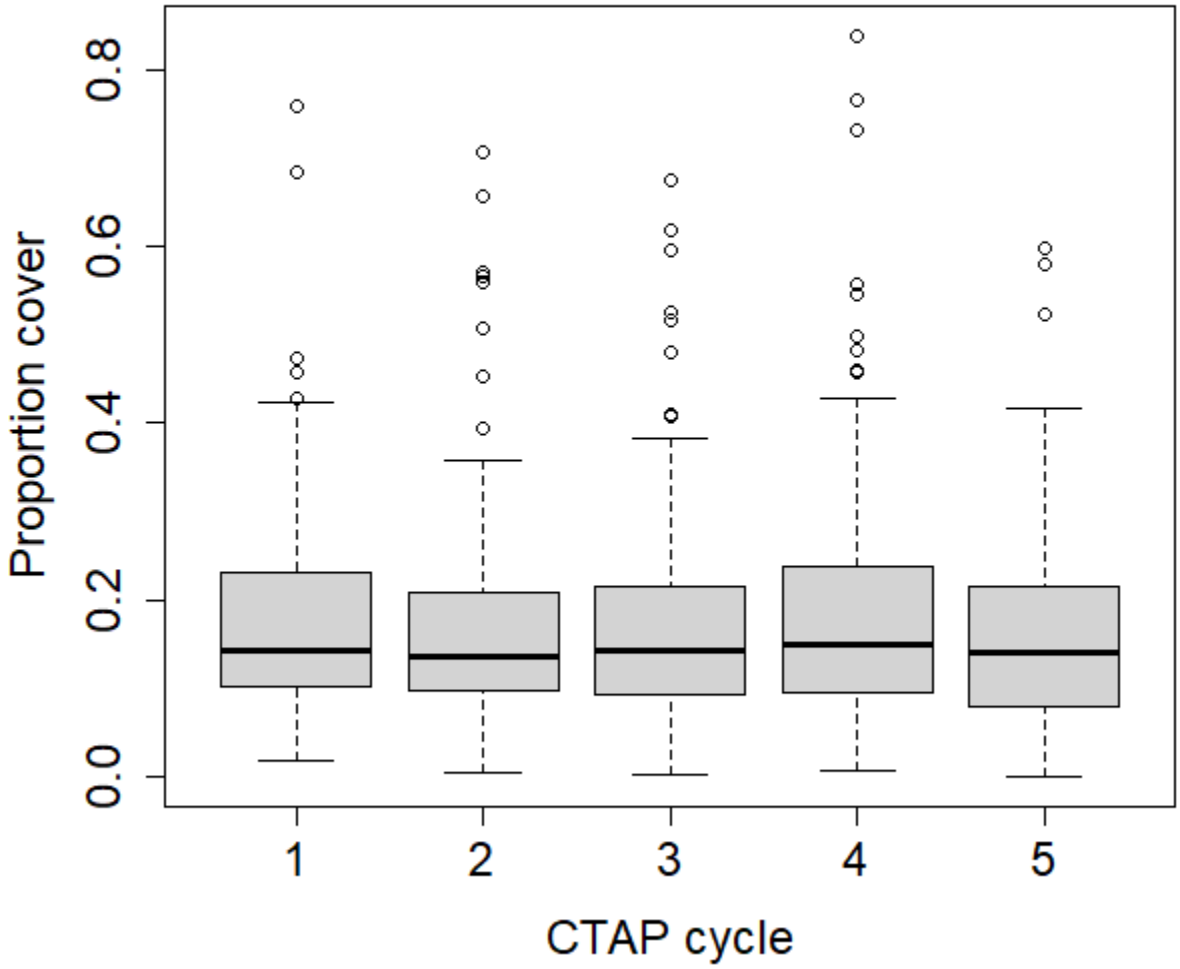


Figure 16. Trends in abundance of plants with flowers that attract beetles at CTAP forest sites. This figure is based on analysis of data from CTAP, the Critical Trends Assessment Program, which has randomly selected sites on public and private land across Illinois. Analyses were conducted on log-transformed values for plant abundance (specifically proportion cover), but we present untransformed values here. We did not find statistical support for a change in abundance through time.

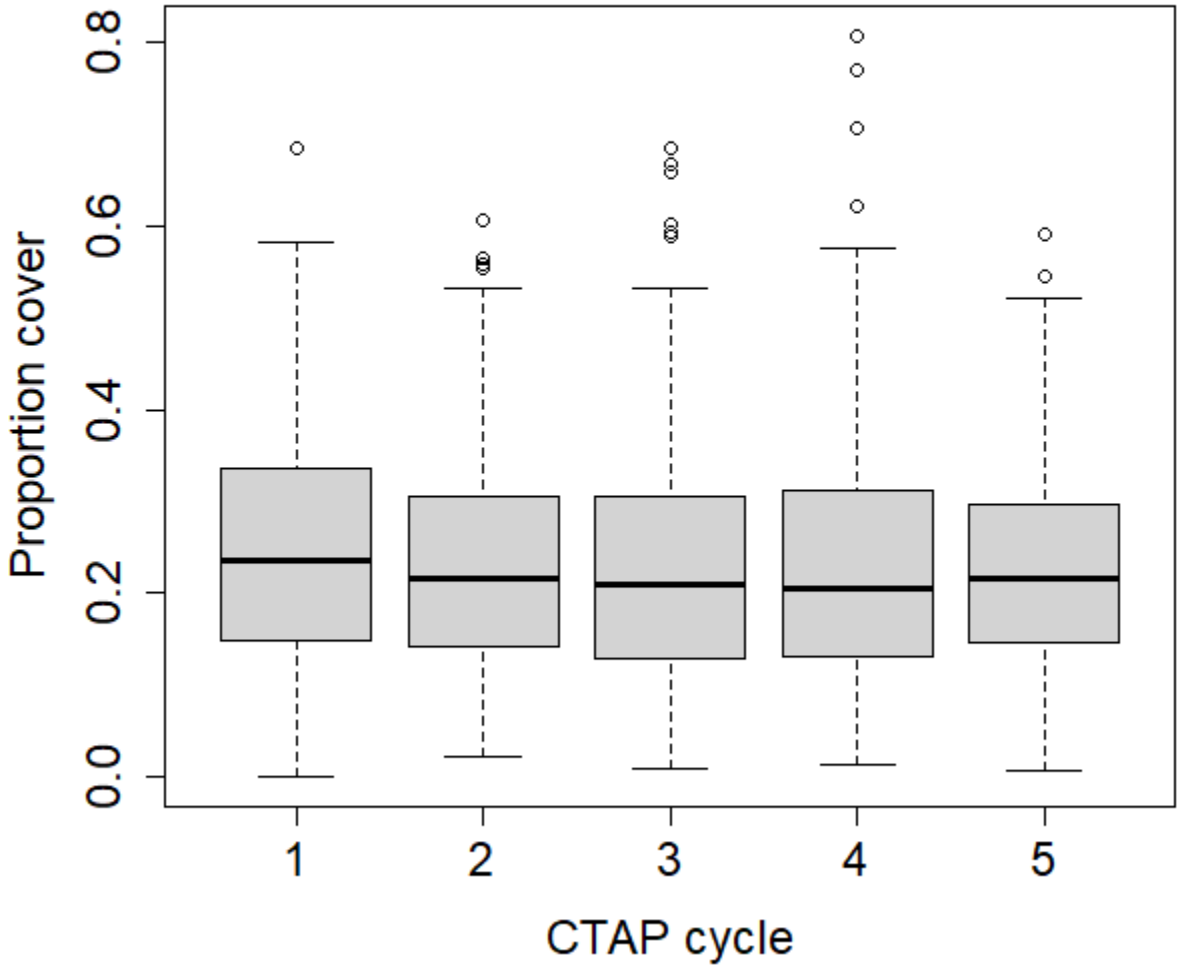


Figure 17. Map of density or absence of *Asclepias verticillata* at observational study sites. The density of *A. verticillata* was measured with the Integrated Monarch Monitoring Program protocol. All study sites were grasslands on Illinois Department of Natural Resources property. Red circles indicate the absence of *A. verticillata*. Blue circles indicate sites where the species was present, and the size of the circle is proportional to the square root of the log-transformed density of the species.

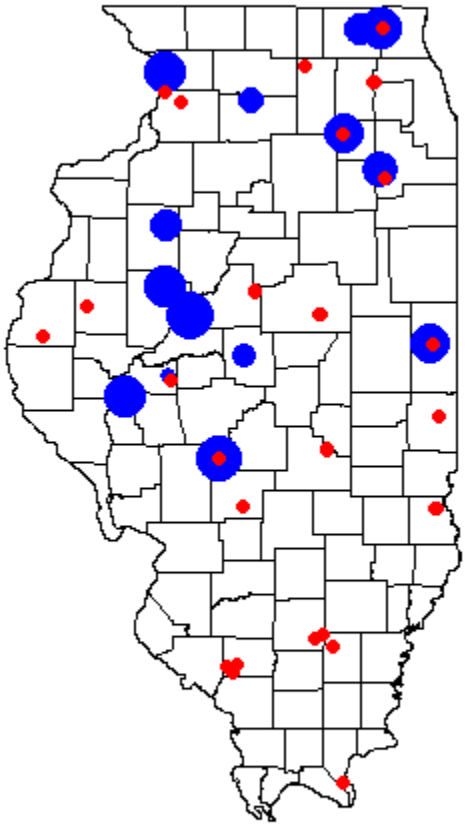


Figure 18. Distribution of latitude values for sites with and without *Asclepias verticillata*. We found statistical support for *A. verticillata* being more likely to be found at northern sites.

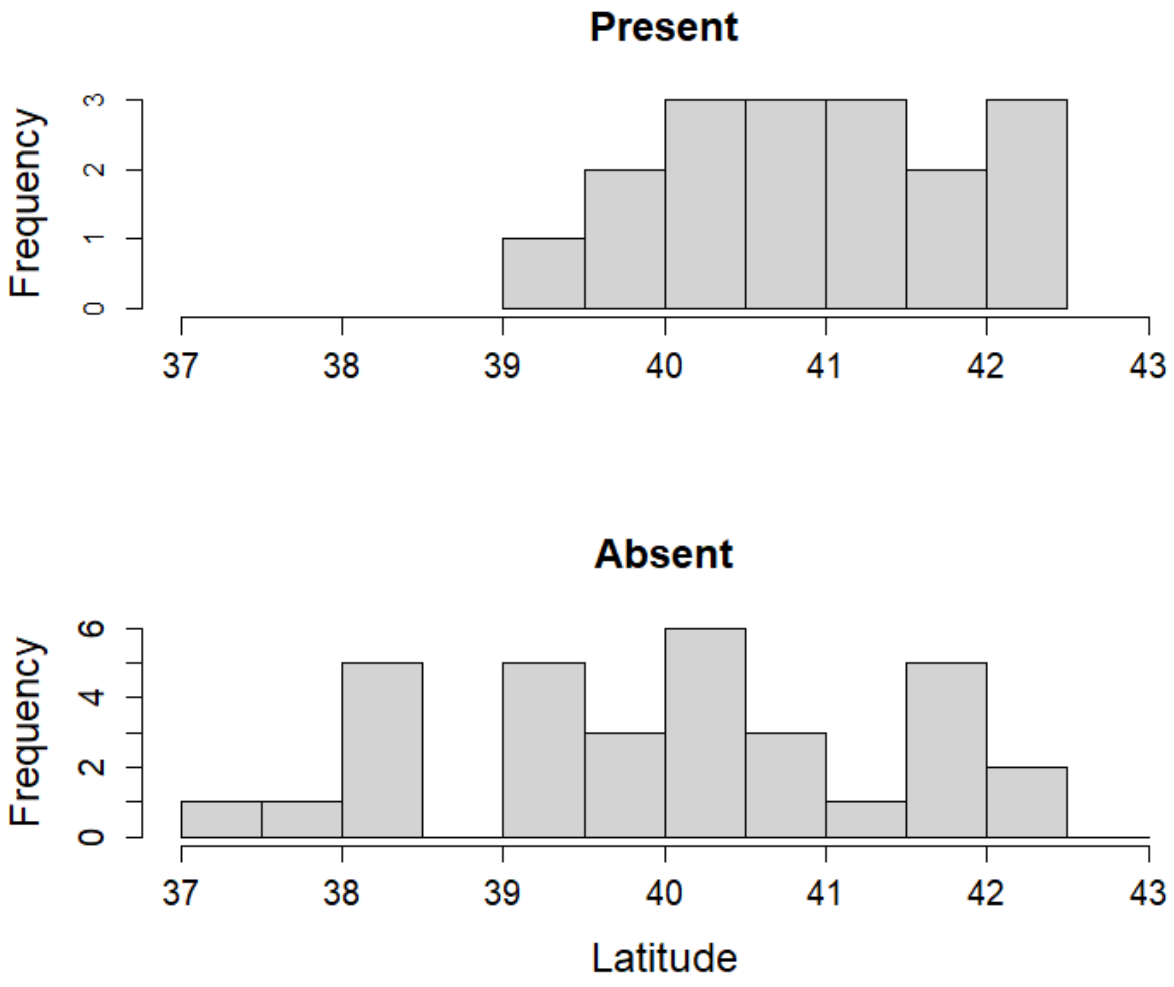


Figure 19. Distribution of longitude values for sites with and without *Asclepias verticillata*. We found weak statistical support for *A. verticillata* being more likely to be found at western sites.

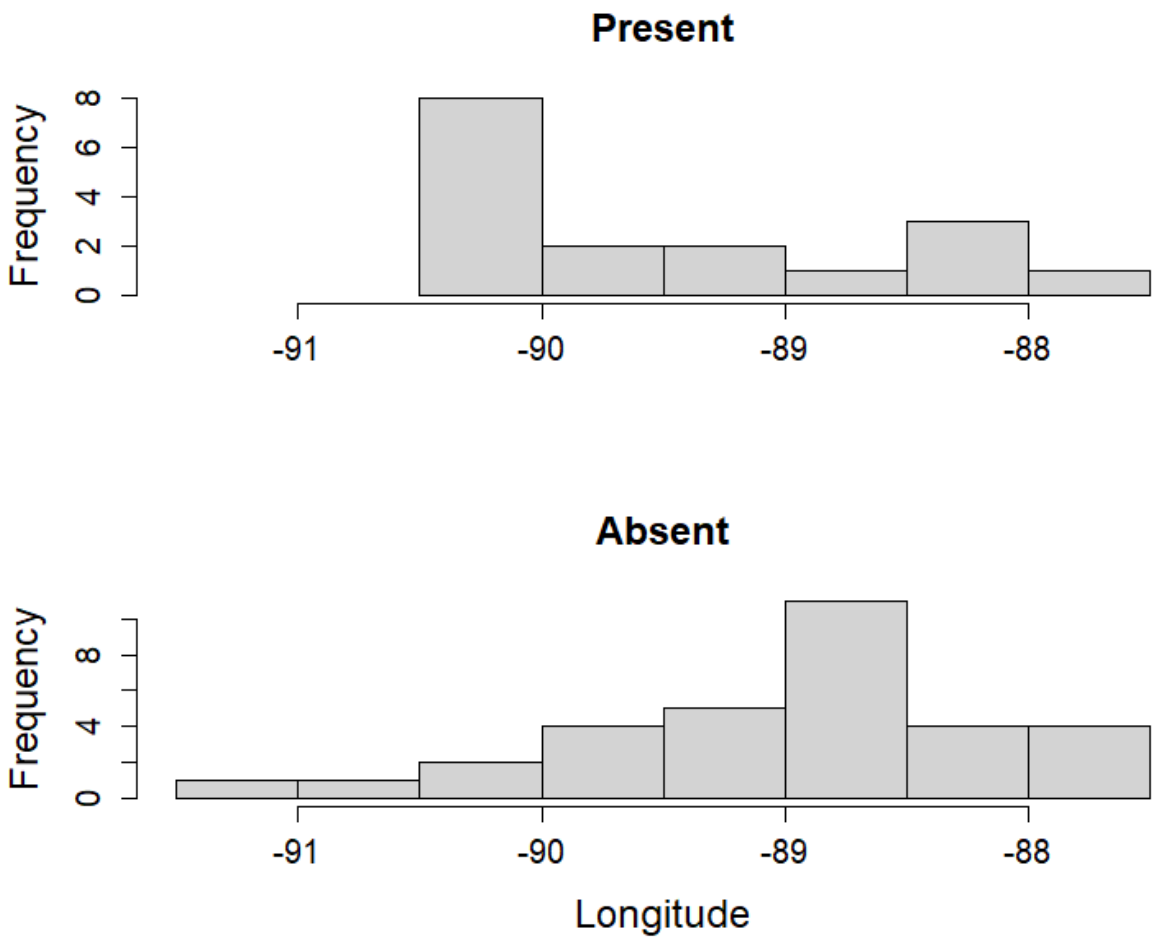


Figure 20. Density of *Asclepias syriaca* at three different grassland types found on Illinois Department of Natural Resources property. We found statistical support for a difference in *A. syriaca* density among habitat types.

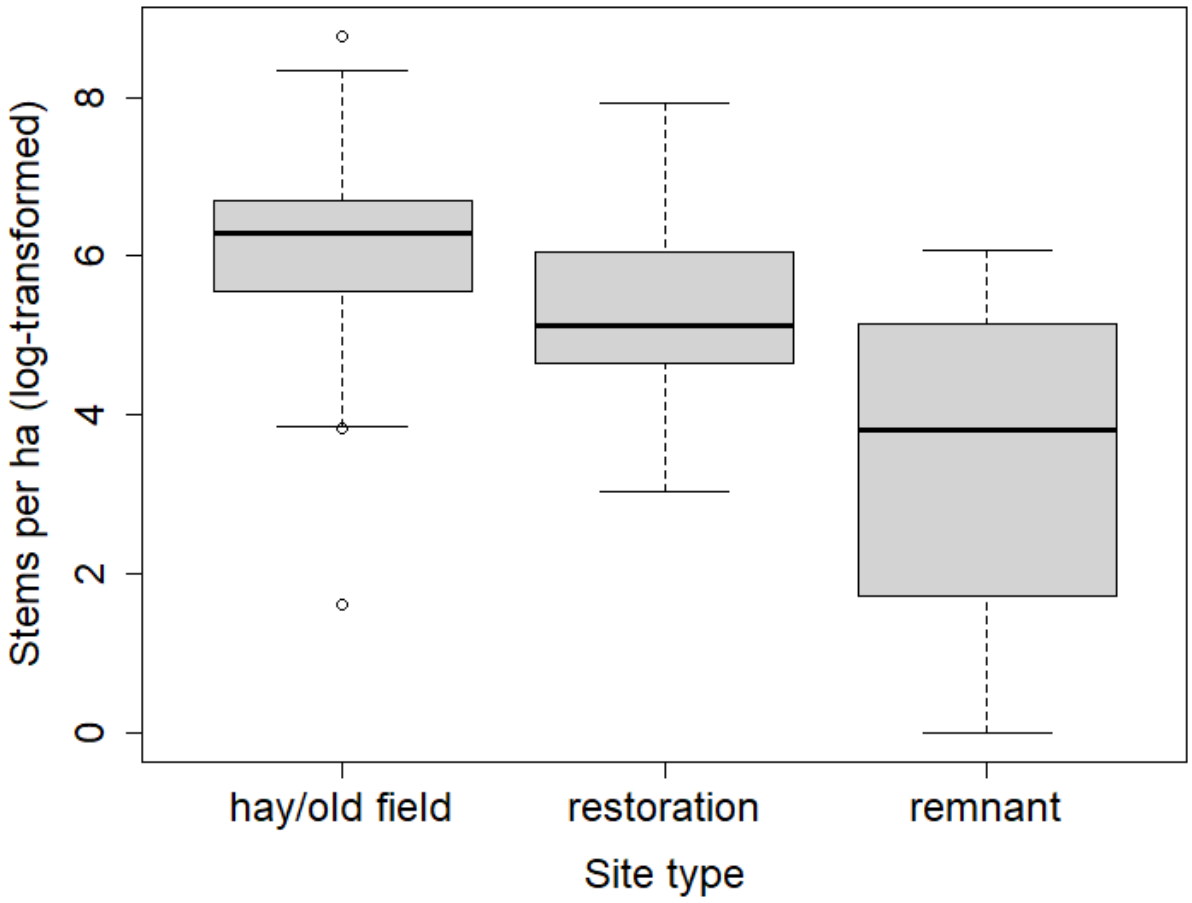


Figure 21. Map of density of *Asclepias syriaca* at observational study sites. The density of *A. syriaca* was measured with the Integrated Monarch Monitoring Program protocol. All study sites were grasslands on Illinois Department of Natural Resources property. One red circle indicates a site where we did not find *A. syriaca*. Blue circles indicate sites where the species was present, and the size of the circle is proportional to the square root of the log-transformed density of the species.

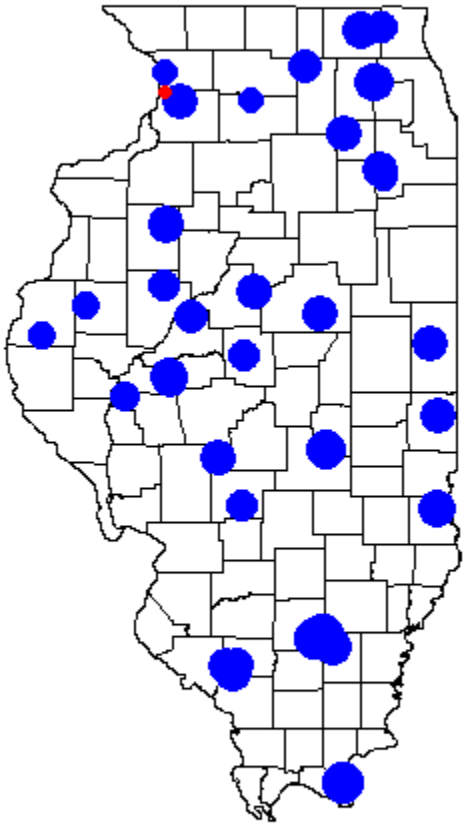


Figure 22. Density of *Asclepias syriaca* as a function of latitude of study site. Density (as stems per hectare) is log(*x*+1)-transformed. We found statistical support for a negative trend, where southern sites have a greater density of *A. syriaca*. This trend was not found when excluding sites south of 39°N. The curve is derived from the intercept and slope of the latitude fixed effects terms from the linear mixed-effects model that included this variable. The marginal R^2 for the mixed-effects model is 0.12, and the conditional R^2 is 0.30.

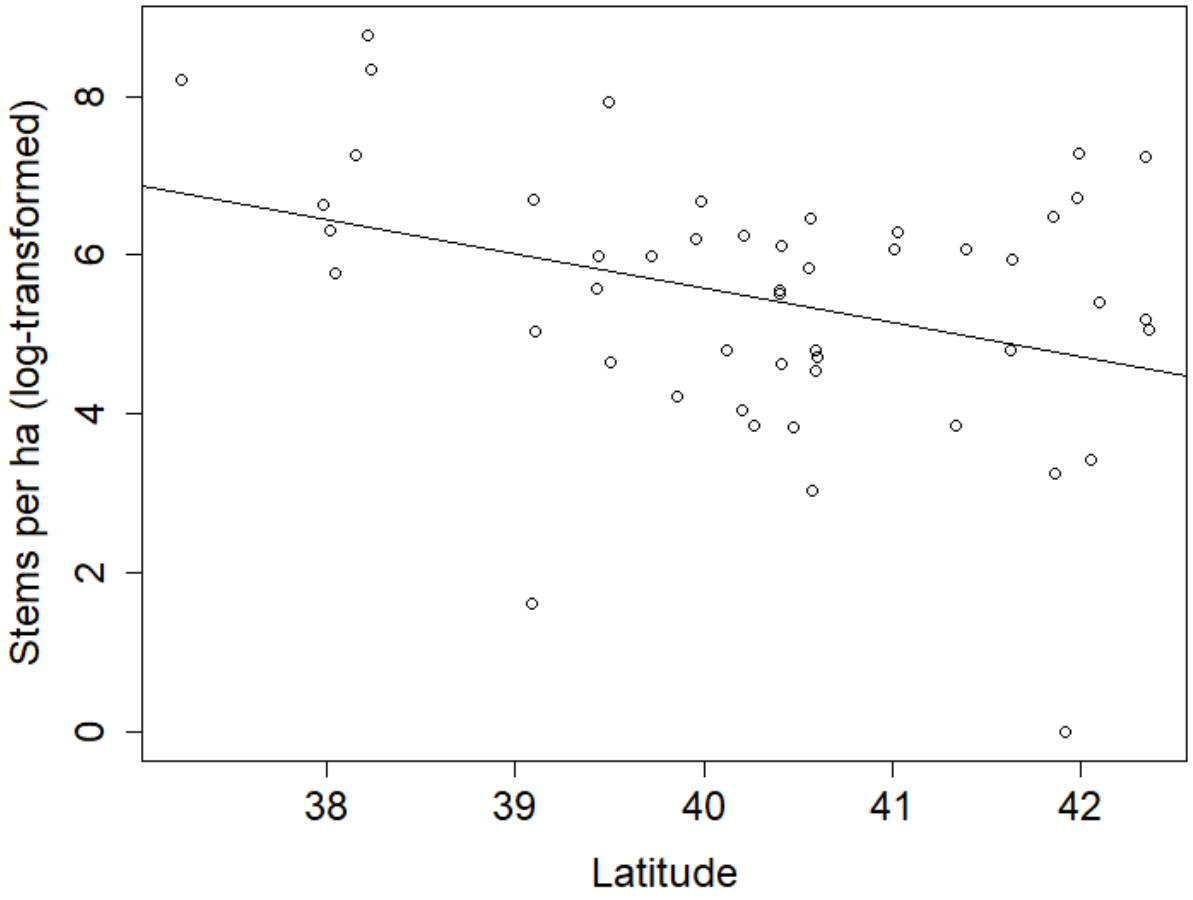


Figure 23. Density of *Asclepias syriaca* as a function of longitude of study site. Density (as stems per hectare) is log(*x*+1)-transformed. We found statistical support for eastern sites having greater densities of *A. syriaca*. The curve is derived from the intercept and slope of the longitude fixed effects terms from the linear mixed-effects model that included this variable.

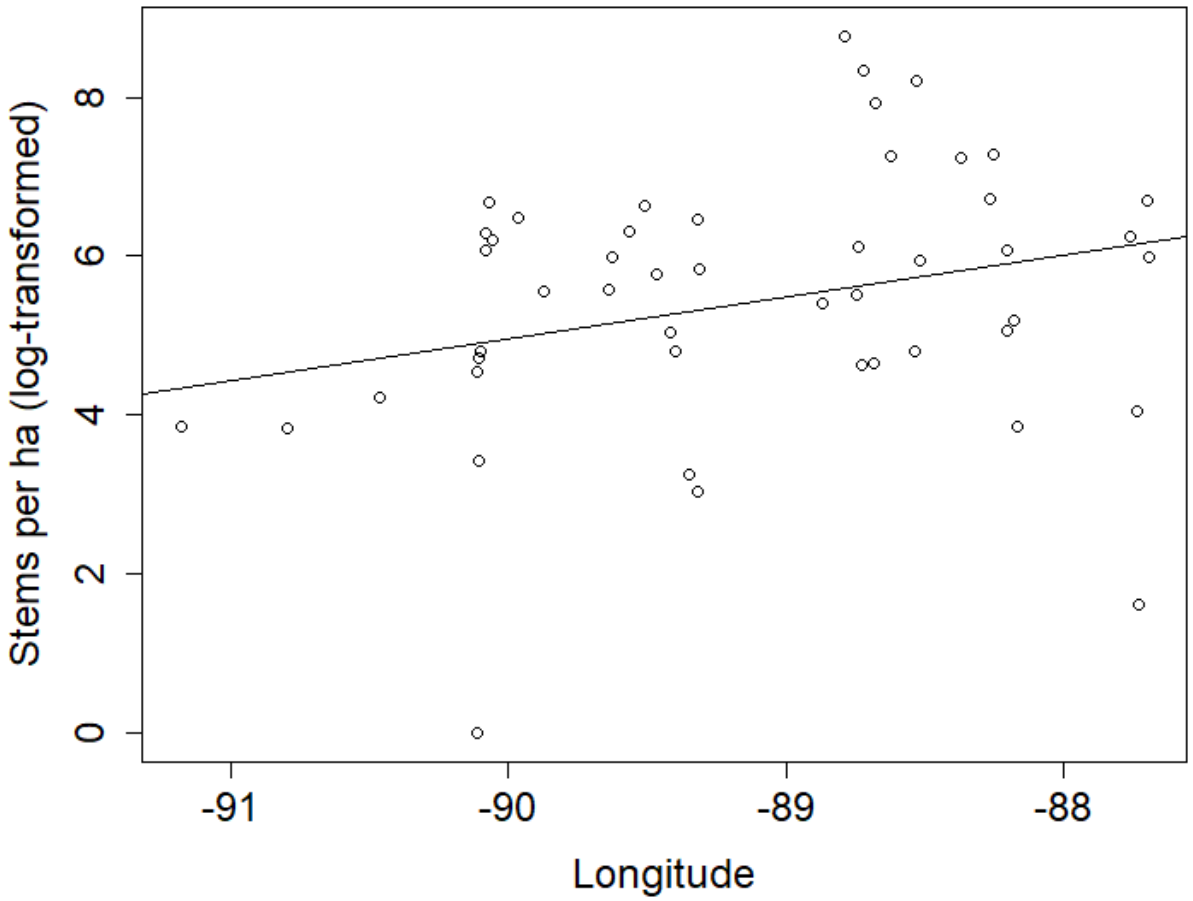


Figure 24. Neonates per plant found for each observational site visit, across years and rounds of sampling. These data were collected from spontaneously occurring milkweeds using the Integrated Monarch Monitoring Protocol. We separated statistical analyses for each round. No data for round 1 were collected in 2020. We found statistical support for differences among years in rounds 2 and 3, with 2022 being an especially poor year for monarch reproduction (difference between years was not tested in round 1).

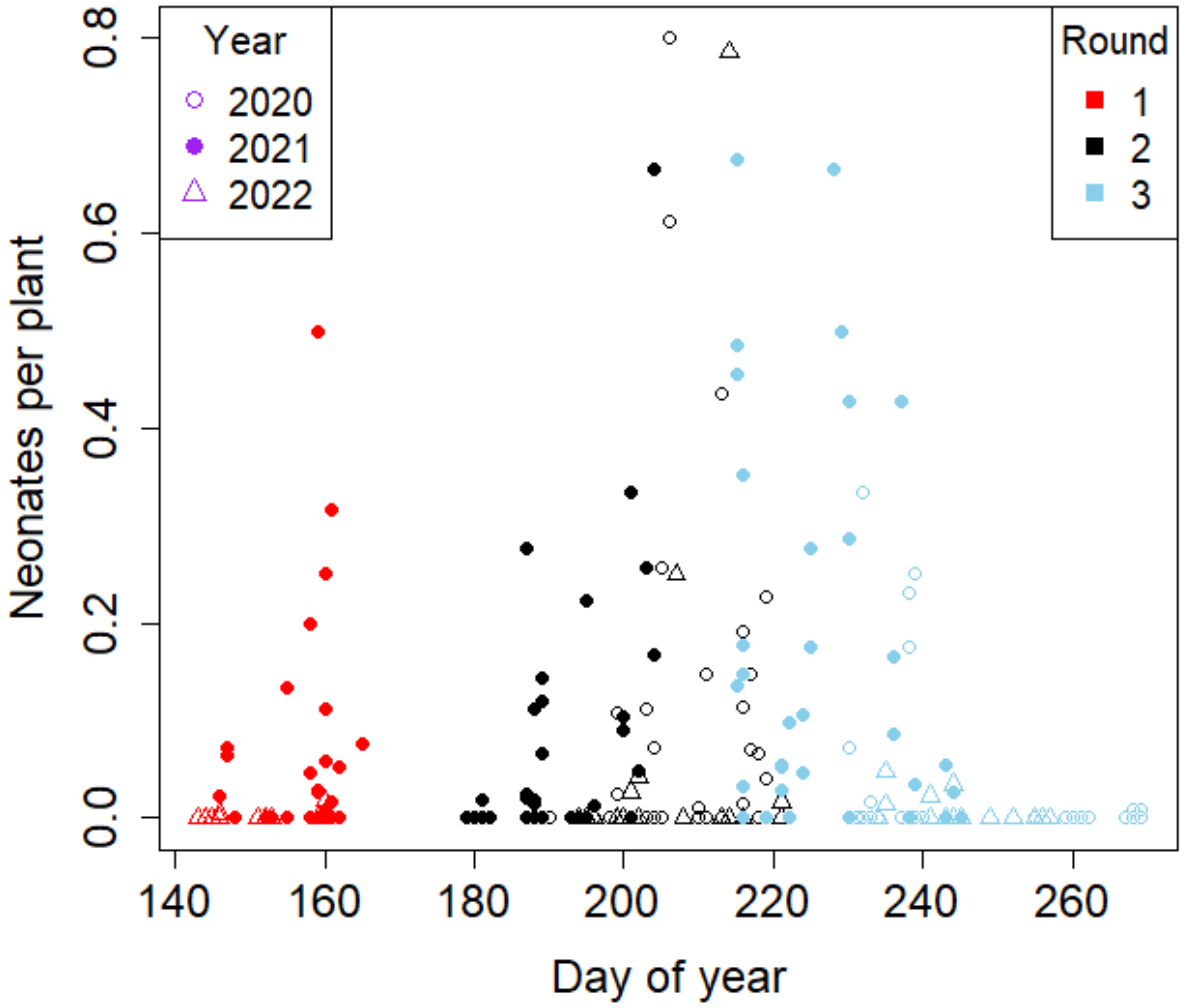


Figure 25. Neonates per plant found during each observational site visit, as a function of latitude. These data were collected from spontaneously occurring milkweeds using the Integrated Monarch Monitoring Protocol. We found statistical support for a positive association with latitude during all sampling rounds.

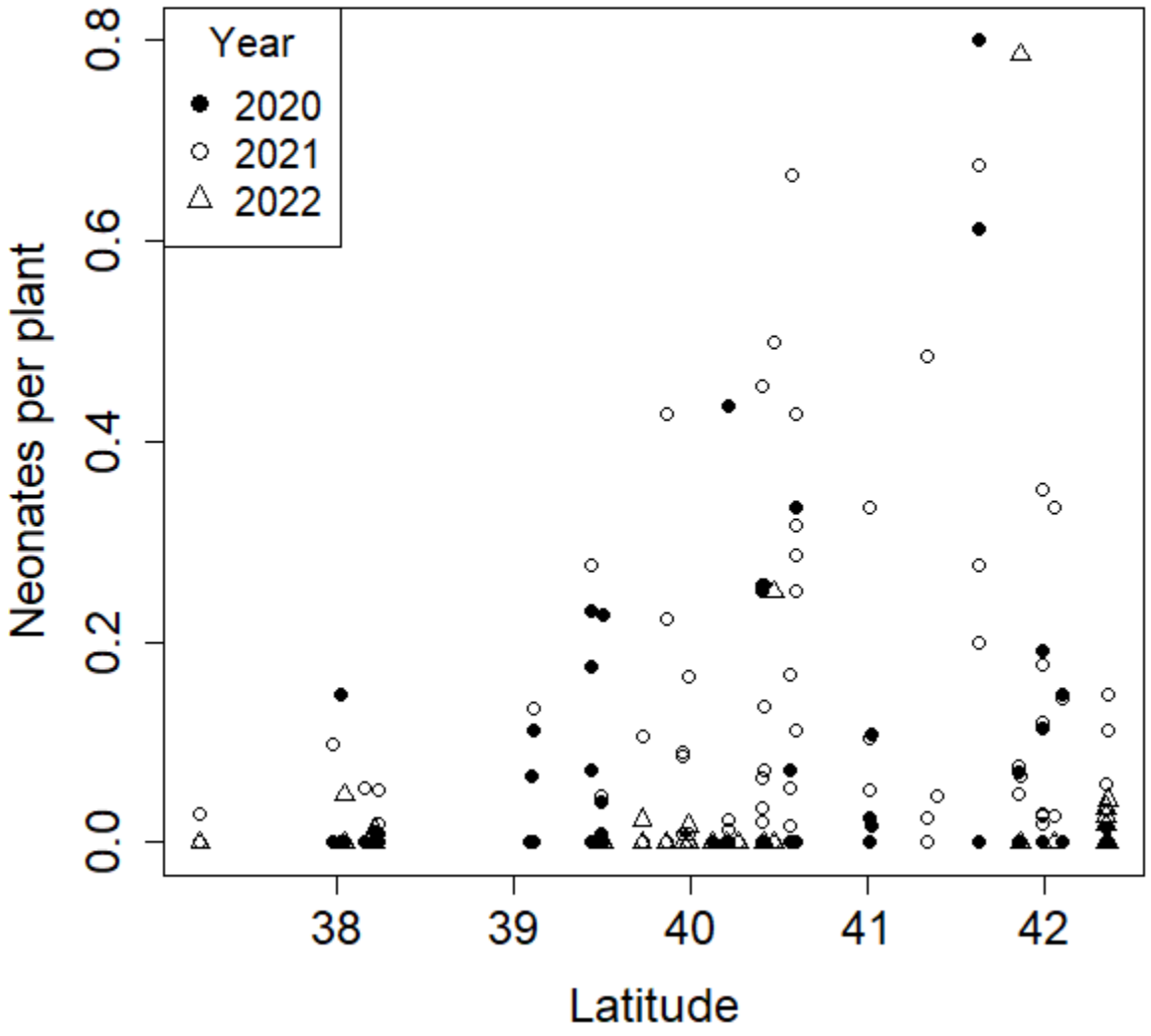


Figure 26. Neonates per plant found during each observational site visit, as a function of the milkweed density at the site. These data were collected from spontaneously occurring milkweeds using the Integrated Monarch Monitoring Protocol. Milkweed density, as stems per hectare, was summed across all species other than *A. verticillata*, and then log(*x*+1)-transformed. This value for milkweed density was largely determined by the density of *A. syriaca*. We found statistical support for a negative association with milkweed density in rounds 2 and 3.

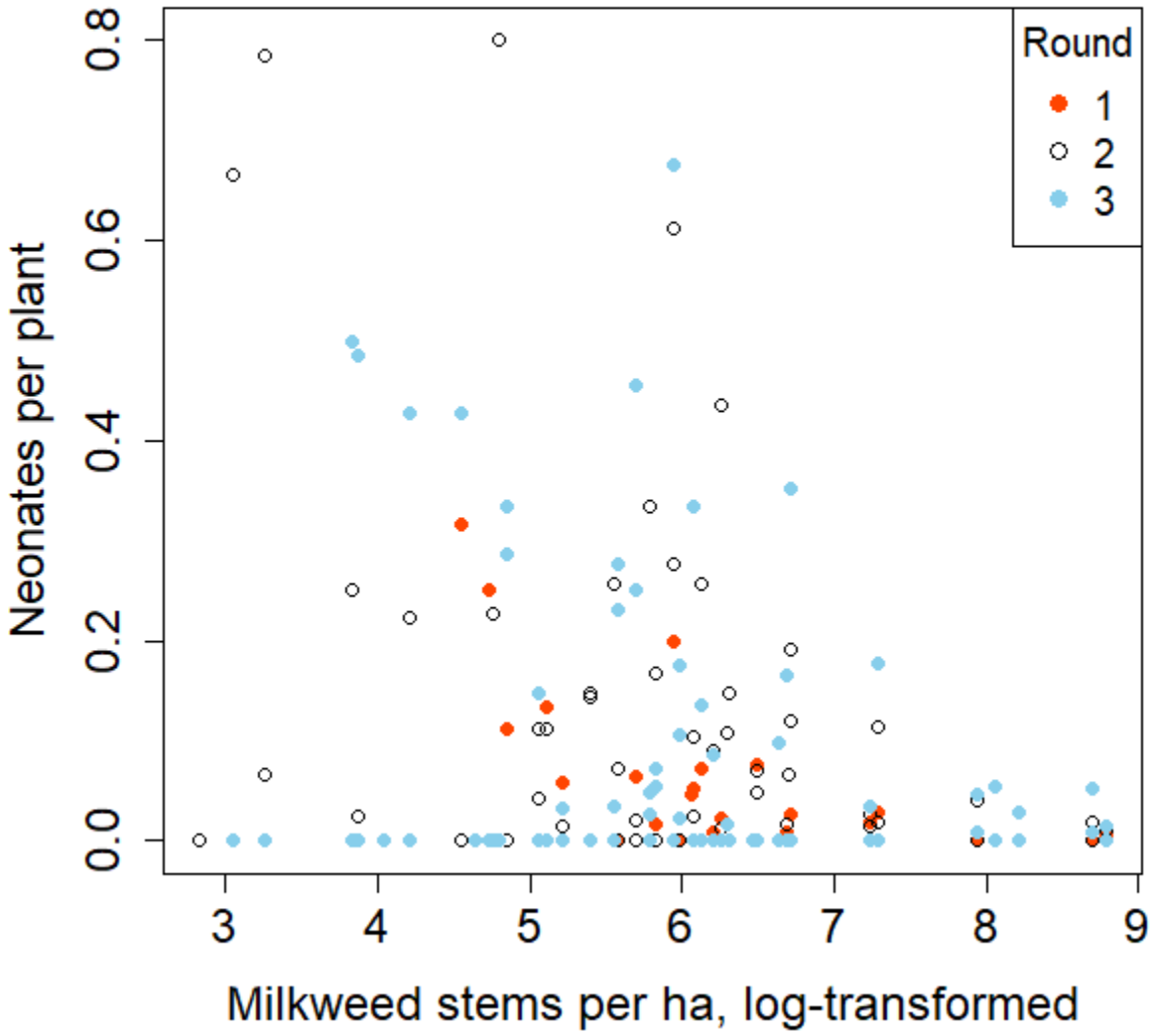


Figure 27. Neonates per plant found during each observational site visit, as a function of the abundance of blooming plants during the site visit. These data were collected from spontaneously occurring milkweeds using the Integrated Monarch Monitoring Protocol. Bloom abundance was log(*x*+1)-transformed. We found weak and mixed statistical support for a relationship that differs among rounds.

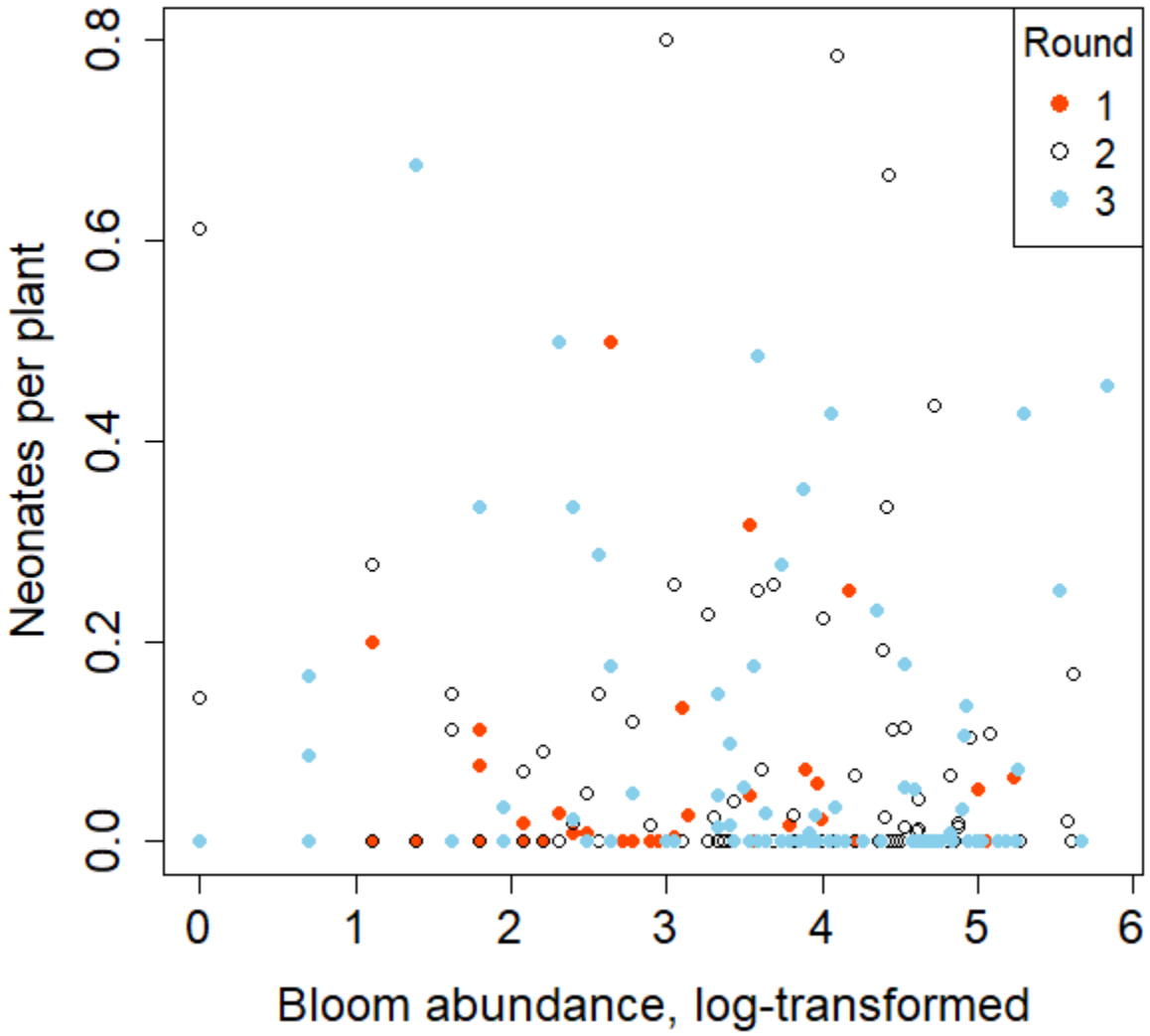


Figure 28. Mean number of adult monarchs observed per site visit, for each year of study and sampling round. These data were collected from Illinois Department of Natural Resources grasslands while utilizing the Integrated Monarch Monitoring Program protocol. Error bars indicate the standard error.

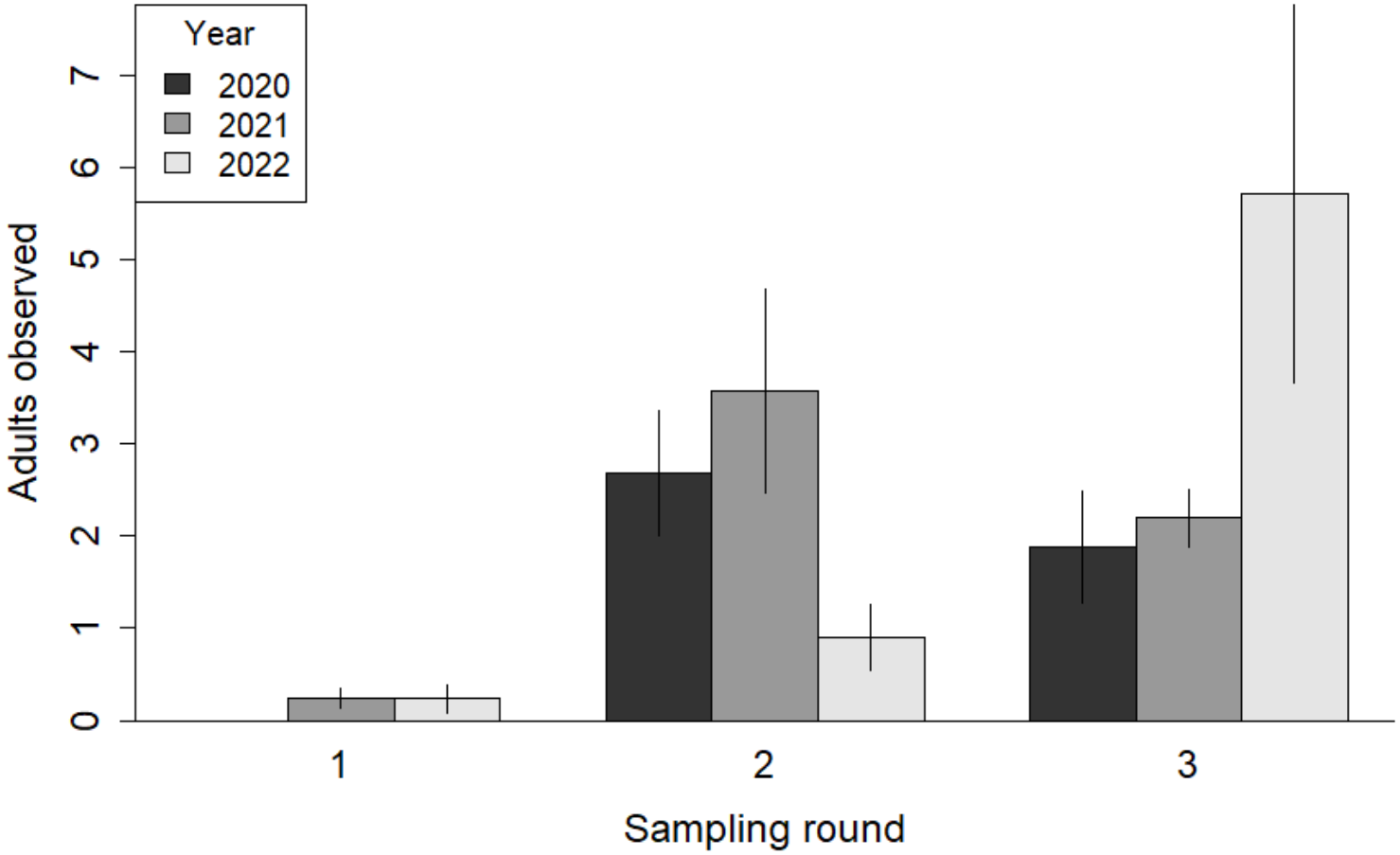


Figure 29. Mean number of adult monarchs observed per site visit as a function of the diversity of blooming plants, separated by sampling round. These data were collected from DNR grasslands while utilizing the IMMP protocol. Bloom diversity was measured as the inverse of the Simpson's Index, see Methods for details. We found stronger statistical support for a positive relationship during the first sampling period, and evidence for a weaker relationship in the third round (no pattern in the second round). Bloom diversity is rounded to the nearest integer for this figure, but analyses were completed on values which were not rounded. Error bars indicate the standard error.

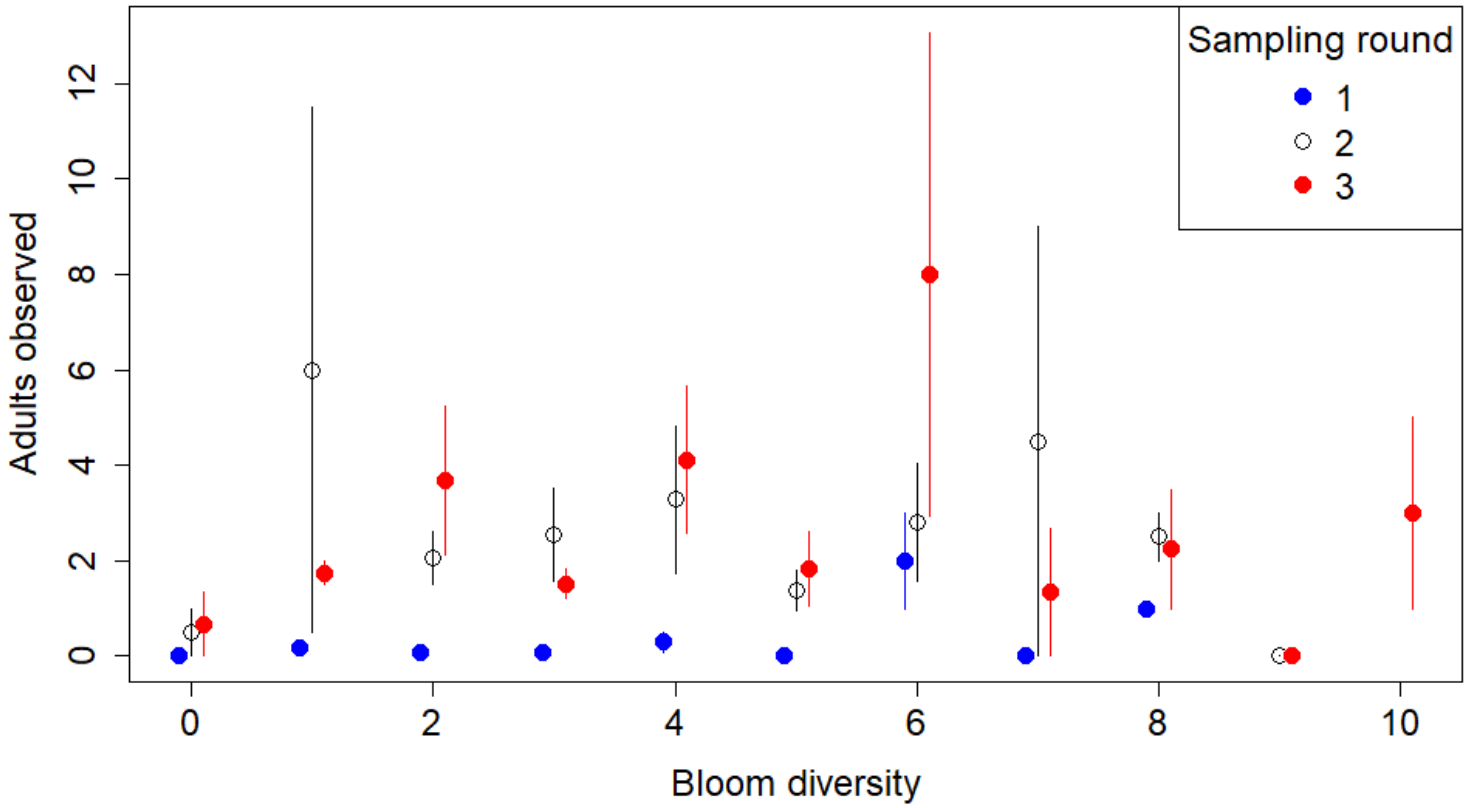


Figure 30. Mean number of adult monarchs observed per site visit as a function of the presence of absence of *A. verticillata*, separated by sampling round. These data were collected from DNR grasslands white utilizing the IMMP protocol. We found some statistical support for a positive association between *A. verticillata* presence and the number of adults observed during the second round of sampling. Error bars indicate the standard error.

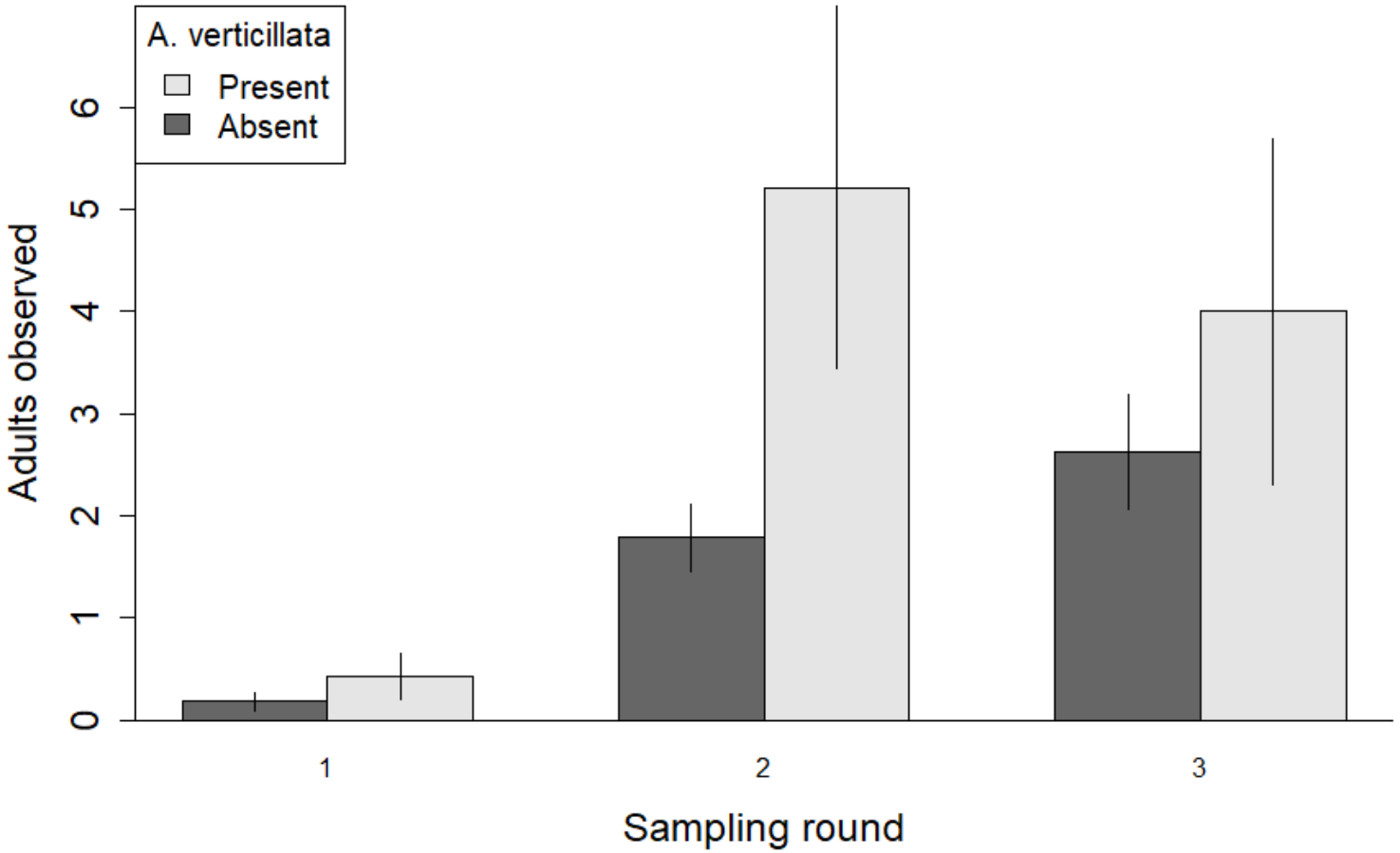


Figure 31. Mean number of adult monarchs observed per site visit as a function of the abundance of blooming plants, separated by sampling round. These data were collected from DNR grasslands while utilizing the IMMP protocol. We found strong statistical support for a positive relationship during the third sampling period. Blooming abundance was log(*x*+1)-transformed for statistical analyses, and transformed values are presented here. Bloom abundance values are rounded to the nearest integer for this figure, but analyses were completed on values which were not rounded. Error bars indicate the standard error.

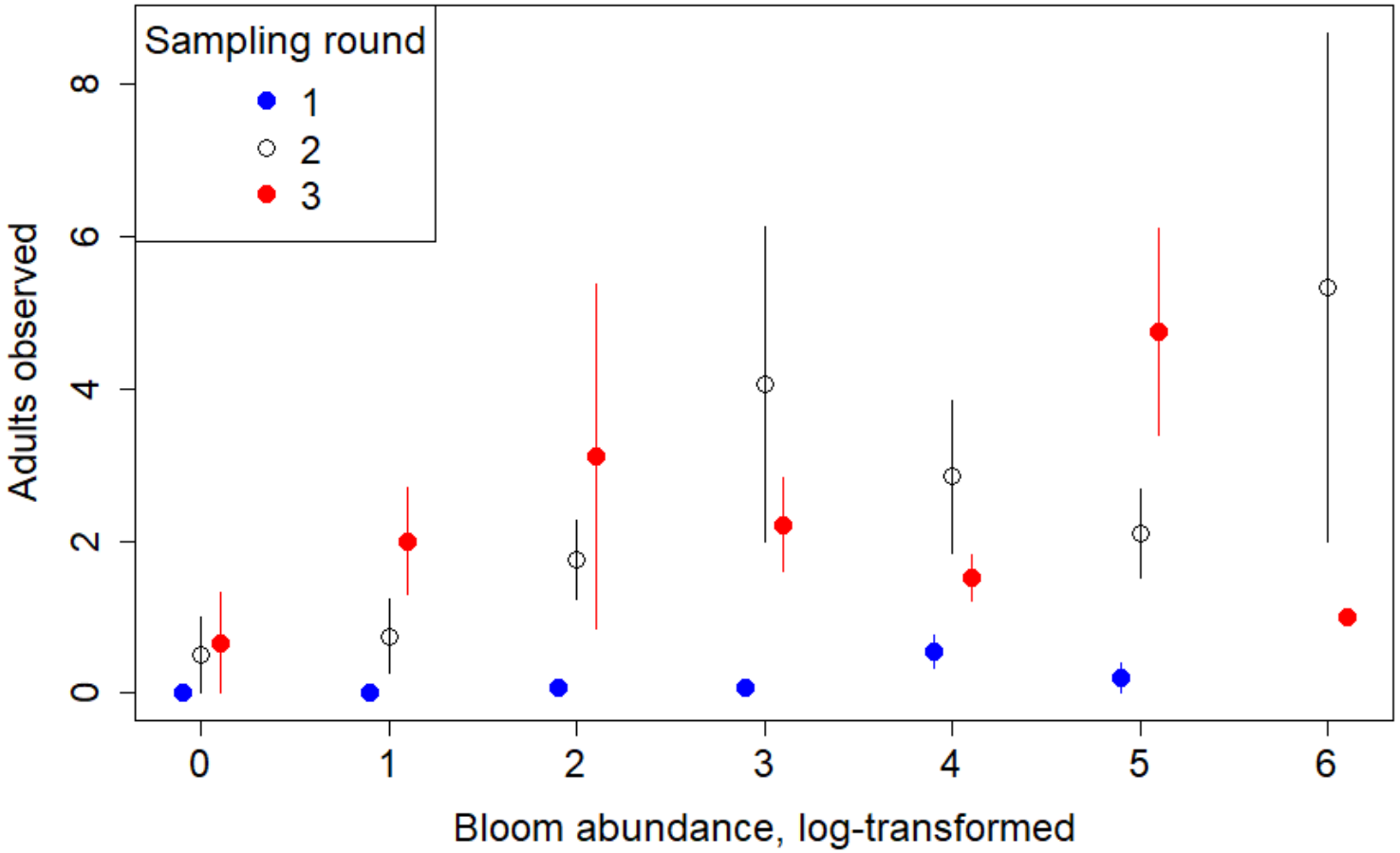


Figure 32. Mean number of adult monarchs observed per site visit as a function of the abundance of milkweed plants, separated by sampling round. These data were collected from DNR grasslands white utilizing the IMMP protocol. The densities of milkweeds were summed across all species other than *A. verticillata*. We found some statistical support for a positive relationship during the first and second sampling periods. Milkweed density was log(x+1) transformed for statistical analysis, and the values are rounded to the nearest integer in this figure for display purposes only. Error bars indicate the standard error.

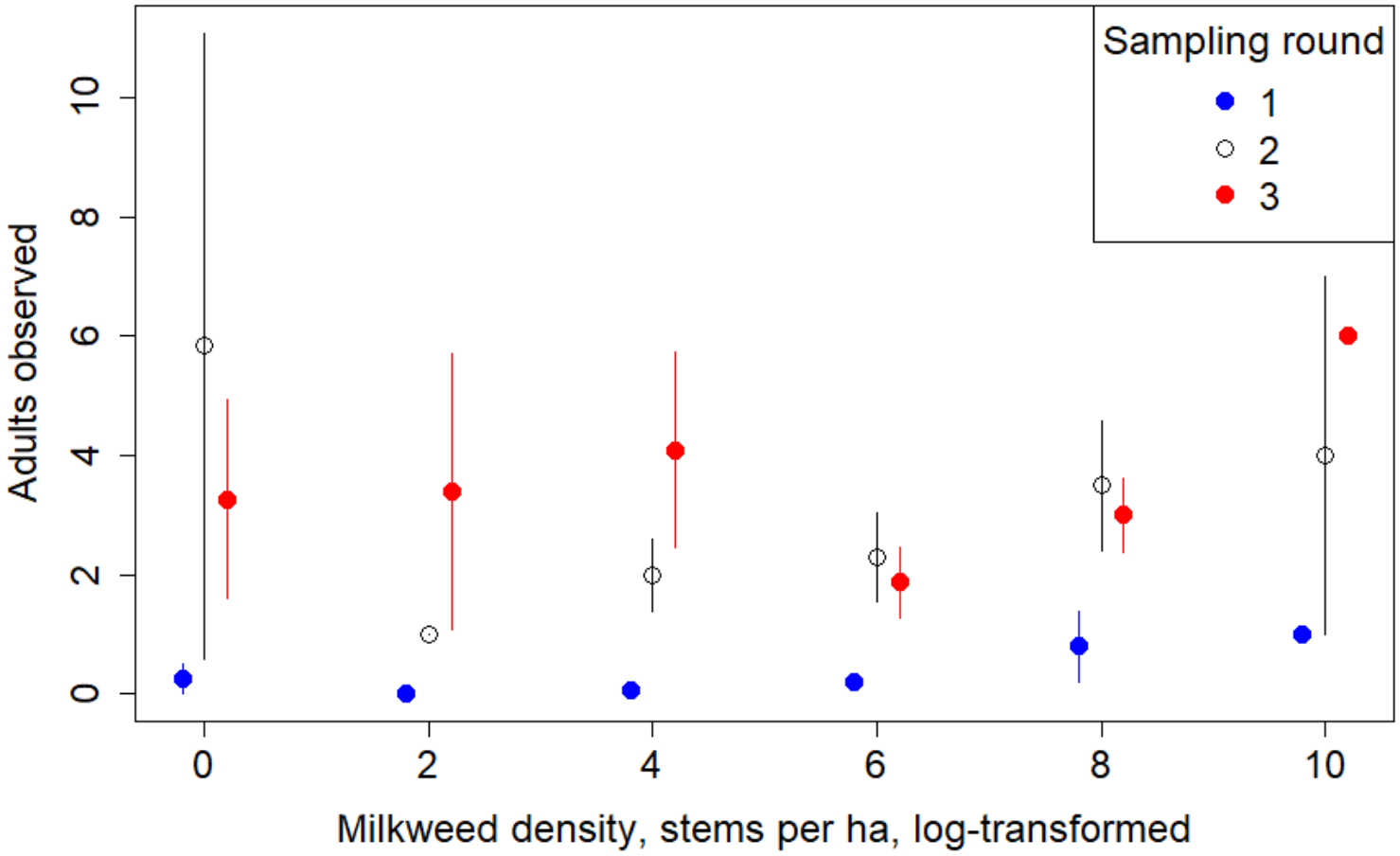


Figure 33. Mean number of adult monarchs observed per site visit as a function of the proportion of developed landcover within 5 km, separated by sampling round. These data were collected from DNR grasslands white utilizing the IMMP protocol, and from remotely sensed data. We found statistical support for a negative relationship during the first and third sampling periods. Proportion of developed landcover is rounded to the nearest tenth for this figure, but analyses were completed on values which were not rounded or transformed. Error bars indicate the standard error.

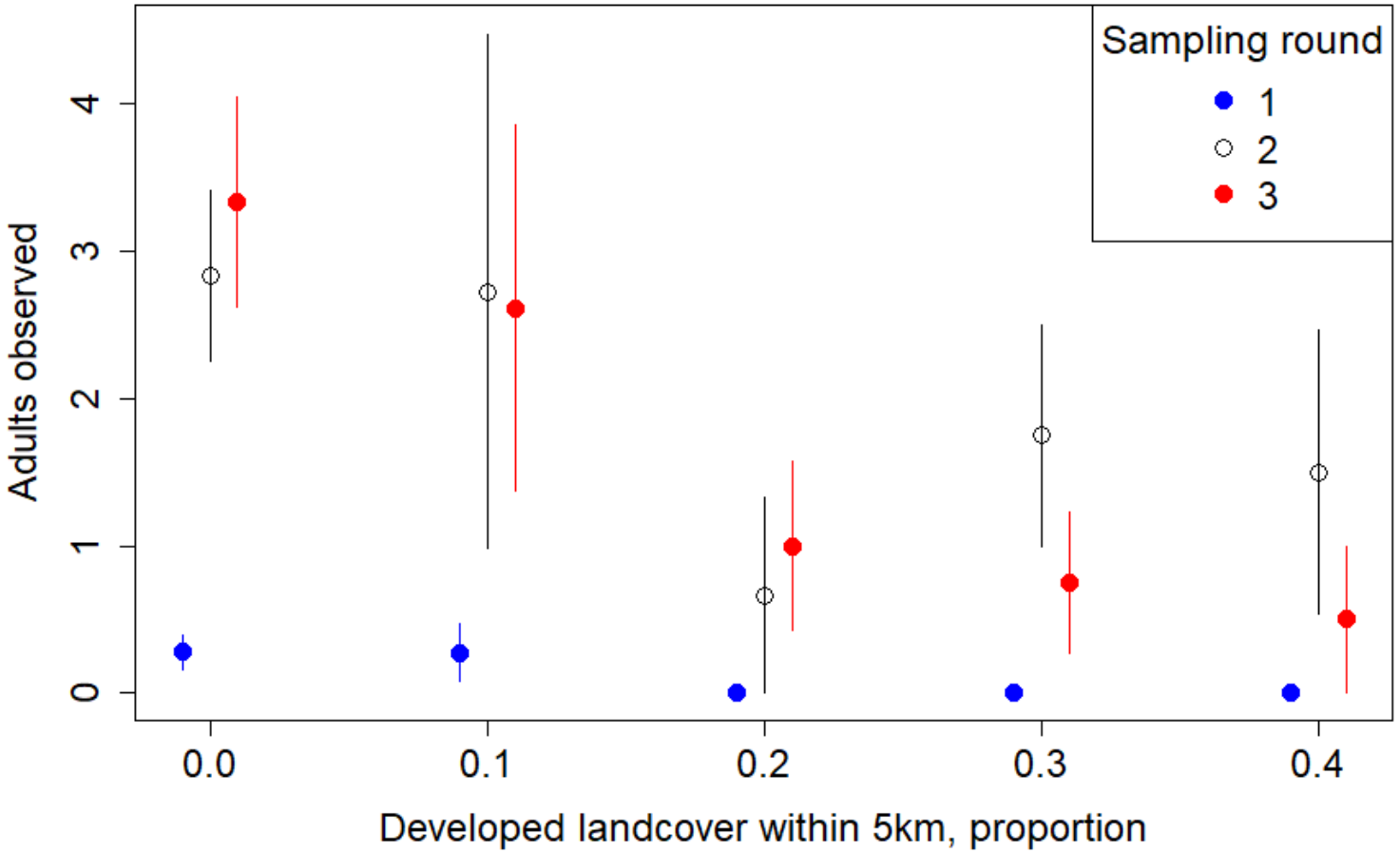


Figure 34. Neonates per plant found on transplanted milkweeds of two species, separated by year. We found strong statistical support for a difference between milkweed species, where *A. incarnata* had greater numbers of neonates. Error bars indicate the standard error.

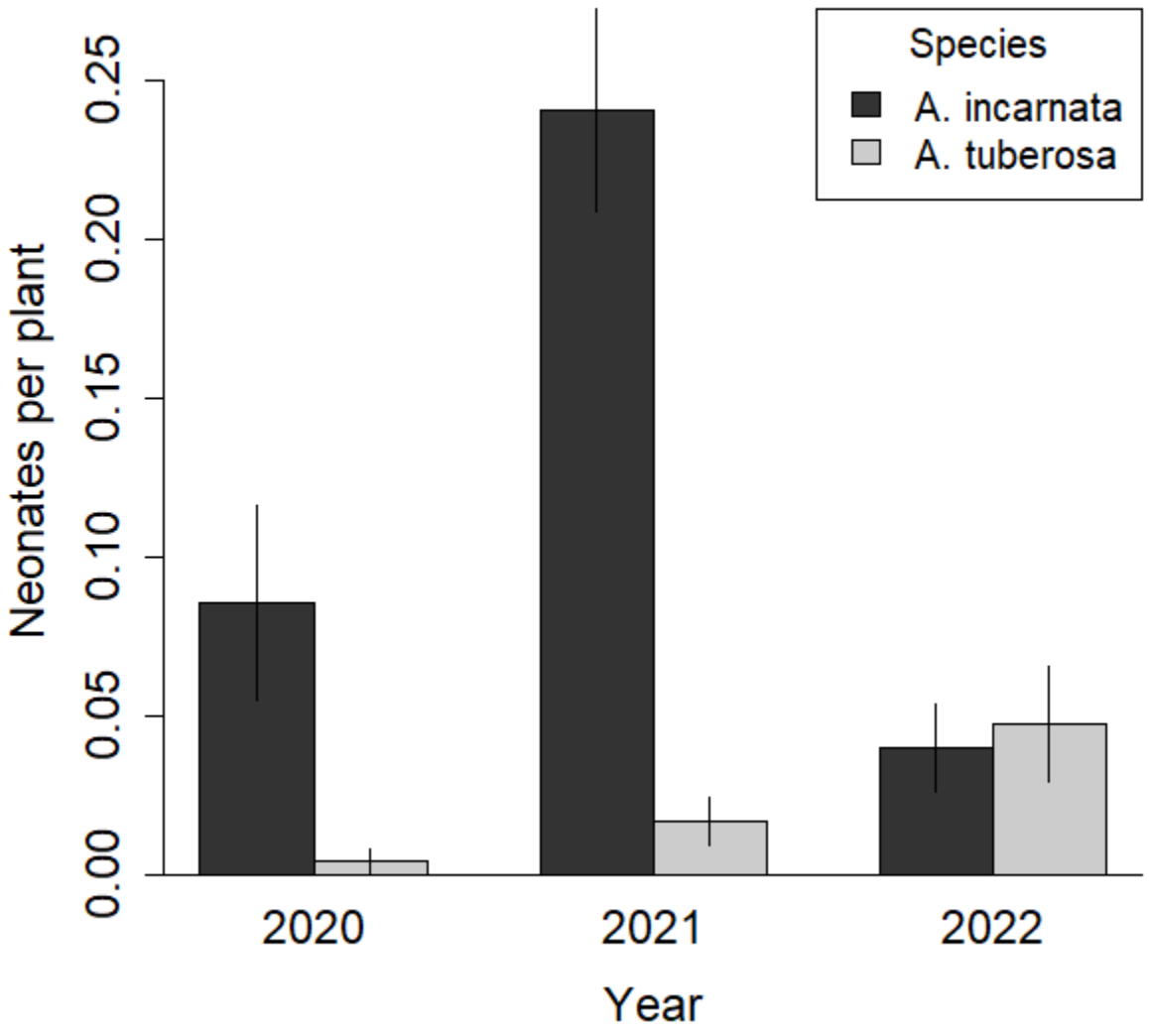


Figure 35. Neonates per plant found on transplanted *Asclepias incarnata* in three habitat types, and three planting patch sizes. We found strong statistical support for an interaction between site type and patch size in predicting the number of neonates per plant. There were more neonates on smaller patches in lawns, but more neonates on larger patches in the other two habitat types. Additionally, lawns had far greater numbers of larvae than the other two habitat types. Error bars indicate the standard error.

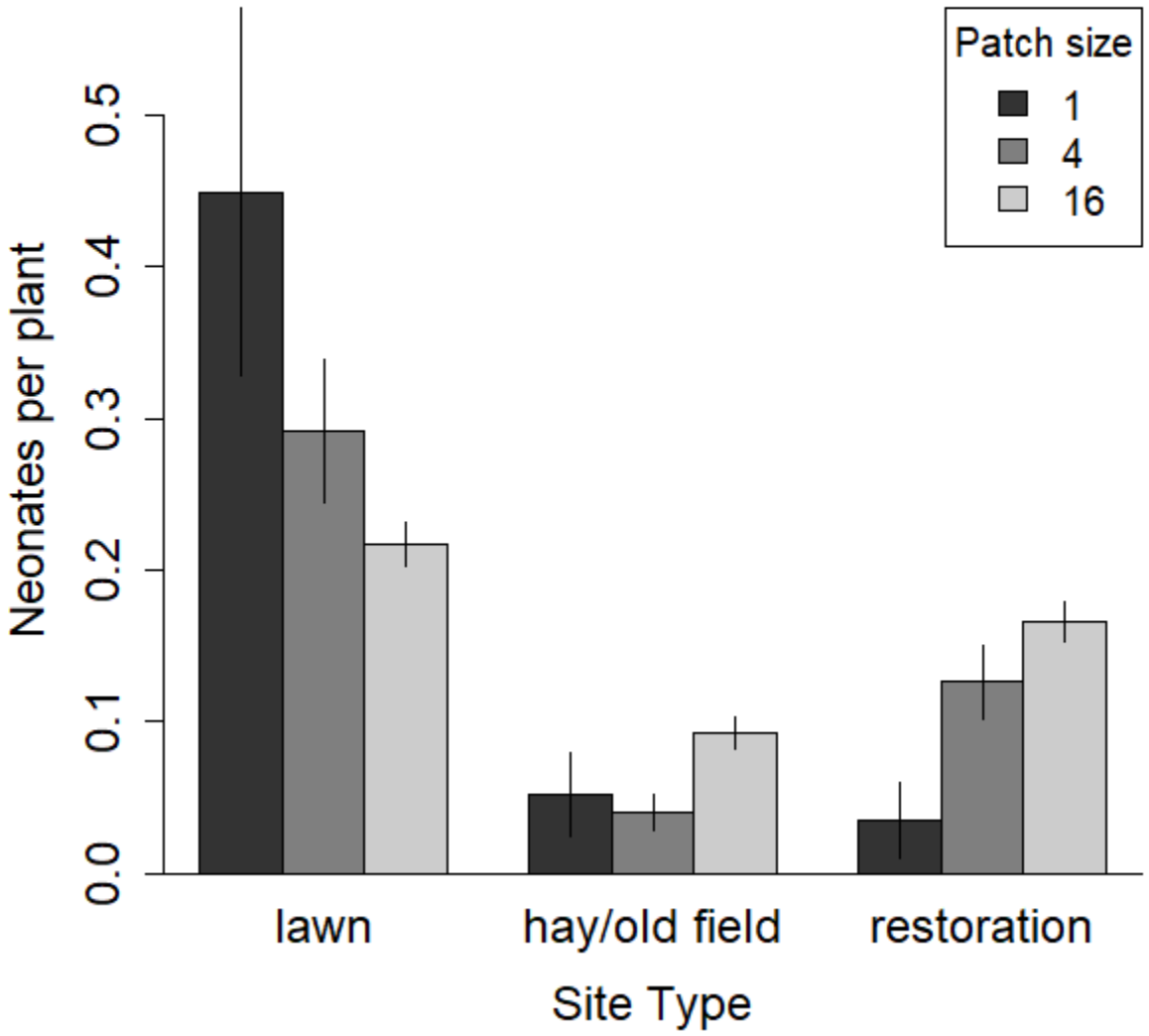
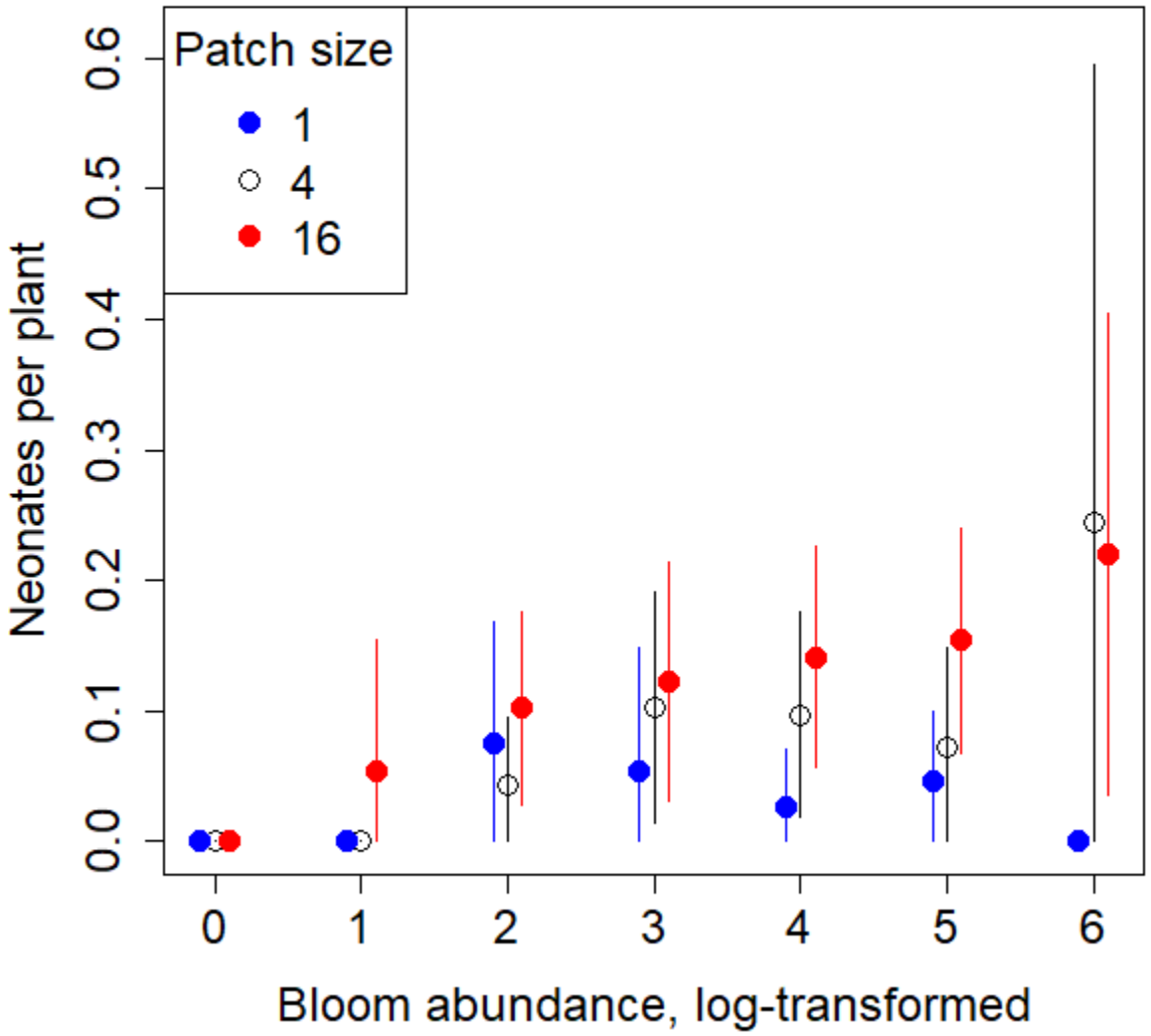


Figure 36. Neonates per plant found on transplanted *Asclepias incarnata* as a function of blooming plant abundance in the surrounding grassland, separated by three planting patch sizes. The blooming abundance was log(*x*+1)-transformed, and in this figure values are rounded to the nearest whole digit for visualization purposes (but analysis was conducted on continuous values). When only considering grasslands (that is, no lawns), the two variables that best predicted the number of neonates per *A. incarnata* individual were blooming abundance (positive relationship) and planting patch size (more neonates on larger patches). Error bars indicate the standard error.



Appendix 1

Study Site Information

This Appendix gives information about each study site. Sites are grouped by Illinois Department of Natural Resources property. Site description, coarse classification used for analyses (either ‘remnant’, ‘restoration’, ‘hay/old field’, or ‘lawn’), and site code used in Figures, Tables, and Supplementary Data Sets are given. Additional information on known management actions are summarized. Information about elements of the project the site was included in are given, plus the years the sites were studied and coordinate locations.

The sites in this Appendix are sorted by the abbreviated site code.

Property Name: Argyle Lake State Park
Two sites

Site name / code: Argyle 2 / argyle2
Site type: Old field
Coarse classification: Hay/old field

Known management actions: mowing of perimeter, including part of plot area

Years surveyed:
2021, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.4708709	-90.79854

Approximate milkweed planting coordinates:

Latitude	Longitude
40.44953	-90.80334

Site name / code: Argyle lawn / argylelawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.46014	-90.80104

Property name: Ayers Sand Prairie
One site

Site name / code: Ayers 1 / ayers1
Site type: Remnant dry sand prairie
Coarse classification: Remnant

Known management actions: Prescribed burns every 2-3 years with woody species managed through herbicide spot treatments. Burned in 2021

Years surveyed:
2021, 2022

Included in:
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed:
A. syriaca, *A. verticillata*, and *A. viridiflora*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
42.0529791	-90.10661

Notes: This is an Illinois Nature Preserve.

Property name: Bull Valley State Fish and Wildlife Area
Two sites

Site name / code: Bull Valley 2 / bull2
Site type: Old field, cool season grassland
Coarse classification: Hay/old field

Known management actions: None recent, or unknown

Years surveyed:
2020, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
42.34255	-88.37273

Approximate milkweed planting coordinates:

Latitude	Longitude
42.34269	-88.37270

Site name / code: Bull Valley lawn / bulllawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed: 2020, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
42.34244	-88.37178

Property name: Coffeen Lake State Fish and Wildlife Area
Two sites

Site name / code: Coffeen 1 / coffeen1
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Seeding of *A. tuberosa, A. sullivantii, A. incarnata,* and other native species, burning every 1-2 years, selective mowing, selective herbicide

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. hirtella, A. tuberosa*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.10415	-89.41744

Approximate milkweed planting coordinates:

Latitude	Longitude
39.10513	-89.41839

Site name / code: Coffeen Lawn / coffeenlawn
Site type: Lawn
Coarse classification:Lawn

Year surveyed: 2020, 2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
39.07132	-89.41319

Property name: Crawford County Fish & Wildlife Area
Three sites

Site name / code: Crawford 1 / crawford1
Site type: Old field with woody encroachment
Coarse classification: Hay/old field

Known management actions: Unknown, but appears to be none recent

Years surveyed:
2020, 2022

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.09902	-87.70028

Approximate milkweed planting coordinates:

Latitude	Longitude
39.09836	-87.69903

Site name / code: Crawford 2 / crawford2
Site type: Fallow field, or old field showing signs of past row crop agriculture
Coarse classification: Hay/old field

Known management: Mowing, otherwise unknown

Years surveyed:
2020, 2022

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*, *A. hirtella*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.08678	-87.72752

Approximate milkweed planting coordinates:

Latitude	Longitude
39.0871	-87.72781

Site name / code: Crawford lawn / crawfordlawn
Site type: Lawn
Coarse classification: Hay/old field

Year surveyed: 2020, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
39.08804	-87.73017

Property name: Cretaceous Hills State Natural Area
One site

Site name / code: Cretaceous 1 / cretaceous1
Site type: Old field (former pasture) with woody encroachment
Coarse classification: Hay/old field

Known management actions: Burning, mowing of perimeter, invasive species control with herbicide (*Lespedeza cuneata*)

Years surveyed:
2021, 2022

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. viridiflora*, *A. tuberosa*, *A. hirtella*, *A. purpurascens*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
37.2256918	-88.5329108

Approximate milkweed planting coordinates:

Latitude	Longitude
37.22559	-88.53163

Property name: Des Plaines State Fish and Wildlife Area
Three sites

Site name / code: Des Plaines 3 / desplaines3
Site type: High quality dolomite prairie and brome grassland
Coarse classification: Remnant

Known management actions: Prescribed burns, removal of invasive shrubs, has been seeded in the past

Years surveyed:
2021 (one visit)

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.3875172	-88.20397

Approximate milkweed planting coordinates:

Latitude	Longitude
41.38768	-88.19973

Notes: Only one survey conducted. The plot was set up within the boundaries of the Land and Water Reserve, which had unmarked boundaries. After learning of this, sampling was ended and planted milkweeds were removed.

Site name / code: Des Plaines 4 / desplaines4
Site type: Old field dominated by cool season grasses
Coarse classification: Hay/old field

Known management actions: Burning, mowing,

Years surveyed:
2021

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.3354407	-88.16988

Approximate milkweed planting coordinates:

Latitude	Longitude
41.33538	-88.16928

Site name / code: Des Plaines lawn / desplaineslawn
Site type: Lawn
Coarse classification: Lawn

Years surveyed:
2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
41.37061	-88.20622

Property name: Double T State Fish and Wildlife Area
Four sites

Site name / code: Double T 1 / doublet1
Site type: Reclaimed strip mine with prairie restoration
Coarse classification: Restoration

Known management actions: Fire every 2 years, chemical and physical invasive species removal, seeding when established

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata, A. incarnata*
Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.59513	-90.10193

Approximate milkweed planting coordinates:

Latitude	Longitude
40.59547	-90.10159

Site name / code: Double T 2 / doublet 2
Site type: Reclaimed strip mine with prairie restoration
Coarse classification: Restoration

Known management actions: Fire every 2 years, chemical and physical invasive species removal, seeding when established

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.59657	-90.10950

Approximate milkweed planting coordinates:

Latitude	Longitude
40.59657	-90.11096

Site code: Double T 4 / doublet4
Site type: Reclaimed strip mine with prairie restoration
Coarse classification: Restoration

Known management actions: Fire every 2 years, chemical and physical invasive species removal, seeding when established

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*
Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.59632	-90.11398

Approximate milkweed planting coordinates:

Latitude	Longitude
40.59587	-90.11555

Site name / code: Double T lawn / doubletlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.58996	-90.10028

Property name: Franklin Creek State Natural Area
Two sites

Site name / code: Franklin 2 / franklin2
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Prescribed burns every 2-4 years, invasive species control, seeding with prairie mix evident

Years surveyed:
2021, 2022

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*, *A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.8645205	-89.35085

Approximate milkweed planting coordinates:

Latitude	Longitude
41.86325	-89.34957

Site name / code: Franklin lawn / franklinlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
41.85710	-89.35189

Property name: Freeman Mine State Habitat Area
Two sites

Site name / code: Freeman 1 / freeman1
Site type: Cool season grassland, old field
Coarse classification: Hay/old field

Known management actions: Mowing, spot herbicide usage, woody plant removal. In distant past, seeding of *A. tuberosa* and other native plants. Burned about 20 years ago (treated as unburned in analyses)

Years surveyed:
2020, 2021

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.43851	-89.62786

Approximate milkweed planting coordinates:

Latitude	Longitude
39.4418	-89.62704

Site name / code: Freeman 2 / freeman2
Site type: Cool season grassland, old field

Known management actions: Mowing, spot herbicide usage, woody plant removal. In distant past, seeding of *A. tuberosa* and other native plants. Burned about 20 years ago (treated as unburned in analyses)

Years surveyed:
2020, 2021

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.43548	-89.63672

Approximate milkweed planting coordinates:

Latitude	Longitude
39.4356	-89.63625

Property name: Thomson-Fulton Sand Prairie Nature Preserve
One site

Site name / code: Fulton 1 / fulton1
Site type: Remnant sand prairie
Coarse classification: Remnant

Known management actions: Pine tree removal, native grass seeding

Years surveyed:
2021, 2022

Included in:
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. viridiflora*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.91826	-90.11517

Note: This site is an Illinois Nature Preserve.

Property name: Jim Edgar Panther Creek State Fish and Wildlife Area
Three sites

Site name / code: Jim Edgar 2 / jim2
Site type: Low diversity grassland
Coarse classification: Hay/old field

Known management actions: Prescribed burn every other year, herbicide use, woody species removal, mowing of paths

Years surveyed:
2021, 2022

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.9886673	-90.0727

Approximate milkweed planting coordinates:

Latitude	Longitude
39.98959	-90.07352

Site name / code: Jim Edgar 3 / jim3
Site type**:** Old field
Coarse classification: Hay/old field

Known management actions: Prescribed burn every other year, woody species removal, mowing of paths

Years surveyed:
2021, 2022

Included in:
Milkweed planting
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.95633	-90.05521

Approximate milkweed planting coordinates:

Latitude	Longitude
39.95565	-90.0577

Site name / code: Jim Edgar lawn / jimlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed: 2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
39.99737	-90.06947

Property name: Kishwaukee River State Fish and Wildlife Area
One site

Site name / code: Kishwaukee 1 / kishwaukee1
Site type: Low diversity grassland
Coarse classification: Hay/old field

Known management actions: Portions of sampled area mowed. Otherwise likely no recent management

Years surveyed:
2020, 2021

Included in:
Milkweed planting data
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
42.09573	-88.87224

Approximate milkweed planting coordinates:

Latitude	Longitude
42.09671	-88.87301

Property name: Mackinaw River State Fish and Wildlife Area
Four sites

Site code: Mackinaw 1 / mackinaw1
Site type: Prairie restoration
Coarse classification: Restoration

Years surveyed:
2020, 2021

Known management actions: Prescribed fire, invasive species removal with spot usage of herbicides

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.57334	-89.31921

Approximate milkweed planting coordinates:

Latitude	Longitude
40.57337	-89.31999

Site name /code: Mackinaw 2 / mackinaw2
Site type: Prairie restoration
Coarse classification: Restoration

Years surveyed:
2020

Known management actions: Prescribed fire, invasive species removal

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.56257	89.31994

Approximate milkweed planting coordinates:

Latitude	Longitude
40.56309	-89.31972

Notes: Unable to survey during 2022 because it was partially plowed.

Site name / code: Mackinaw 3 / mackinaw3
Site type: Prairie restoration
Coarse classification: Restoration

Years surveyed:
2020, 2022

Known management actions: Prescribed fire, invasive species removal with spot usage of herbicides

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.55537	-89.31419

Approximate milkweed planting coordinates:

Latitude	Longitude
40.55405	-89.31459

Site name / code: Mackinaw lawn / mackinawlawn
Site type: Lawn

Year surveyed:
2020, 2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.55692	-89.30240

Property name: Edward R. Madigan State Park
Two sites

Site name / code: Madigan 1 / madigan1
Site type: Old field
Coarse classification: Hay/old field

Known management actions: Prescribed burning, brush removal

Years surveyed:
2020, 2022

Included in:
Floral surveys
Milkweed plantings
Milkweed density estimate

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.11821	-89.39641

Approximate milkweed planting coordinates:

Latitude	Longitude
40.1166	-89.39675

Site name / code: Madigan lawn / madiganlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed: 2020, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.11954	-89.39638

Property name: Samuel Barnum Mead Savanna
One site

Site name /code: Mead 1 / mead1
Site type: Prairie restoration

Known management actions: Prescribed burns, woody species control with herbicide, woody species physical removal, last seeded ~1993

Years surveyed:
2021, 2022

Included in:
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.2664847	-91.17992

Notes: The remnant on this property is an Illinois Nature Preserve. The sampling occurred in the restoration portion of the site, but we did not plant milkweeds.

Property name: Meredosia Hill Prairie
One site

Site name / code: Meredosia 1 / meredosia1
Site type: Remnant hill prairie
Coarse classification: Remnant

Known management actions: Prescribed burns, invasive control

Years surveyed:
2021, 2022

Included in:
Floral Surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.8564698	-90.4662

Notes: This site is an Illinois Nature Preserve.

Property name: Middle Fork State Fish and Wildlife Area
Three sites

Site name / code: Middle Fork 4 / middlefork4
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Yearly prescribed burn

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata, A. sullivantii*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.21319	-87.76318

Approximate milkweed planting coordinates:

Latitude	Longitude
40.2022	-87.73797

Notes: Data sheet for third floral survey was lost

Site code: Middle fork 5 / middlefork5
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Yearly prescribed burn

Years surveyed:
2020, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.20232	-87.73853

Approximate milkweed planting coordinates:

Latitude	Longitude
40.21414	-87.76391

Site name / code: Middlefork lawn / middleforklawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.21194	-87.75527

Property name: Moraine View State Recreation Area
Four sites

Site name / code: Moraine 1 / moraine1
Site type: Old field in early stages of prairie restoration
Coarse classification: Restoration

Known management actions: Prescribed burns every 1-2 years, seeded with mix developed for monarch butterflies

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. tuberosa*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.41429	-88.73727

Approximate milkweed planting coordinates:

Latitude	Longitude
40.41459	-88.73652

Site name / code: Moraine 2 / moraine2
Site type: Old field in early stages of prairie restoration
Coarse classification: Restoration

Known management actions: Prescribed burns every 1-2 years, seeded with mix developed for monarch butterflies

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. tuberosa*

Floral survey and milkweed density estimate coordinates::

Latitude	Longitude
40.40505	-88.74699

Approximate milkweed planting coordinates:

Latitude	Longitude
40.4046	-88.74677

Site name / code: Moraine 3 / moraine3
Site type: Old field in early stages of prairie restoration
Coarse classification: Restoration

Known management actions: Prescribed burns every 1-2 years, seeded with mix developed for monarch butterflies

Years surveyed:
2020, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates::

Latitude	Longitude
40.41234	-88.72707

Approximate milkweed planting coordinates:

Latitude	Longitude
40.41175	-88.72686

Site name / code: Moraine lawn / morainelawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.41229	-88.72433

Property name: Morrison-Rockwood State Park
Two sites

Site name / code: Morrison 2 / morrison2
Site type: Old field, perhaps with some restoration efforts
Coarse classification: Hay/old field

Known management actions: None or unknown

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.84907	-89.96533

Approximate milkweed planting coordinates:

Latitude	Longitude
41.84848	-89.96519

Site name / code: Morrison lawn / morrisonlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
41.84297	-89.96249

Property name: James Pate Phillip State Park
Three sites

Site name / code: Pate 1 / pate1
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Mowing, prescribed burns, herbicide treatment for invasives, stump removal

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.98601	-88.25107

Approximate milkweed planting coordinates:

Latitude	Longitude
41.98055	-88.26196

Site name / code: Pate 2 / pate2
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Mowing, prescribed burns, herbicide treatment for invasives, stump removal, *A. incarnata* seeding and/or plugs

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. incarnata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.98208	-87.76318

Approximate milkweed planting coordinates:

Latitude	Longitude
41.98618	-88.25398

Site name / code: Pate lawn / patelawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
41.97813	-88.25761

Property name: Pyramid State Recreation Area
Four sites

Site name / code: Pyramid 1 / pyramid1
Site type: Reclaimed strip mine
Coarse classification: Hay/old field

Known management actions: Autumn olive removal

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. viridis*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
37.9762	-89.51182

Approximate milkweed planting coordinates:

Latitude	Longitude
37.97594	-89.51340

Site name / code: Pyramid 2 / pyramid2
Site type: Reclaimed strip mine
Coarse classification: Hay/old field

Known management actions: Herbicide treatment

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
38.01307	-89.56546

Approximate milkweed planting coordinates:

Latitude	Longitude
38.0139	-89.56483

Site code: Pyramid 4 / pyramid4
Site type: Reclaimed strip mine
Coarse classification: Hay/old field

Known management actions: Exotic control planned for future

Years surveyed:
2020, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, C. laeve*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
38.03947	-89.46686

Approximate milkweed planting coordinates:

Latitude	Longitude
38.03896	-89.46794

Site name / code: Pyramid lawn / pyramidlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021

Included in:

Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
37.99984	-89.46053

Property name: Sand Ridge State Forest
Two sites

Site name / code: Sand 1 / sand1
Site type: Sandy old field dominated by grasses
Coarse classification: Hay/old field

Known management actions: Burned historically, now mowed

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
40.39693	-89.87476

Approximate milkweed planting coordinates:

Latitude	Longitude
40.39668	-89.87500

Site name / code: Sand Ridge lawn / sandridgelawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
40.39135	-89.87292

Property name: Silver Springs State Fish and Wildlife Area
Three sites

Site name / code: Silver Springs 1 / silversprings1
Site type: Restoration
Coarse classification: Restoration

Known management actions: Burned 5+ years ago, planted with prairie mix

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.62893	-88.53683

Approximate milkweed planting coordinates:

Latitude	Longitude
41.62941	-88.53732

Site name / code: Silver Springs 2 / silversprings2
Site type: Old field
Coarse classification: Hay/old field

Known management actions: Burned and mowed 20+ years ago, no seeding or management otherwise

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.63072	-88.51905

Approximate milkweed planting coordinates:

Latitude	Longitude
41.63139	-88.51718

Site name / code: Silver Springs lawn / silverspringslawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
41.62873	-88.51988

Property name: Snakeden Hollow State Fish & Wildlife Area
Three sites

Site name / code: Snakeden 2 / snakeden2
Site type: Hay field
Coarse classification: Hay/old field

Known management actions: Mowed 3-4 times per season

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
41.00844	-90.08426

Approximate milkweed planting coordinates:

Latitude	Longitude
41.00714	-90.08348

Site name / code: Snakeden 3 / snakeden3
Site type: Hay field
Coarse classification: Hay/old field

Known management actions: Mowed 3-4 times per season, now converted to agricultural field

Years surveyed:
2020

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. verticillata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude

41.02446	-90.08315

Approximate milkweed planting coordinates:

Latitude	Longitude
41.02503	-90.0831

Note: Unable to survey in 2021, most of the plot area was converted to soybeans

Site name / code: Snakeden lawn / snakedenlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
41.01922	-90.07483

Property name: Ten Mile Creek State Fish and Wildlife Area
Four sites

Site name / code: Ten Mile 3 / tenmile3
Site type: Old field
Coarse classification: Hay/old field

Years surveyed:
2020, 2021

Known management actions: Mowing

Included in:
Milkweed plantings
Floral Surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. incarnata*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
38.15378	-88.62064

Approximate milkweed planting coordinates:

Latitude	Longitude
38.15425	-88.61995

Notes: Surveyed only twice in 2021 because of flooded roads

Site name / code: Ten Mile 4 / tenmile4
Site type: Old field
Coarse classification: Hay/old field

Years surveyed:
2020, 2021

Known management actions: Occasional mowing, herbicide spray for invasives, food plots planted throughout unit to set back succession and then left fallow following year. Five acre pollinator plot planted in part of grassland (apparently not overlapping with plot area)

Included in:
Milkweed plantings
Floral Surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, C. laeve*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
38.23613	-88.71907

Approximate milkweed planting coordinates:

Latitude	Longitude
38.23589	-88.7204

Site name / code: Ten Mile 5 / tenmile5
Site type: Old field
Coarse classification: Hay/old field

Years surveyed:
2020, 2022

Known management actions: Invasive control with herbicide, physical removal of locust

Included in:
Milkweed plantings
Floral Surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, C. laeve*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
38.21382	-88.78937

Approximate milkweed planting coordinates:

Latitude	Longitude
38.21396	-88.79005

Site name / code: Ten Mile lawn / tenmilelawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
38.08210	-88.62594

Property name: Volo Bog State Natural Area
Three sites

Site name / code: Volo 1 / volo1
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Prescribed burns every 2-3 years, situational herbicide use, past seeding and/or planting

Years surveyed:
2021, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*, *A. verticillata, A. sullivanti*

Approximate milkweed planting coordinates:

Latitude	Longitude
42.35635	-88.20467

Approximate milkweed planting coordinates:

Latitude	Longitude
42.35374	-88.20350

Site name / code: Volo 2 / volo2
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Prescribed burns every 2-3 years, situational herbicide use, past seeding and/or planting

Years surveyed:
2021, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. tuberosa*

Approximate milkweed planting coordinates:

Latitude	Longitude
42.3466441	-88.17646

Approximate milkweed planting coordinates:

Latitude	Longitude
42.34449	-88.17510

Site name / code: Volo Bog lawn / vololawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
42.35231	-88.18736

Property name: Willow Creek State Natural Area
Two sites

Site name / code: Willow 2 / willow2
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Unknown

Years surveyed:
2021, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.7220919	-87.69556

Approximate milkweed planting coordinates:

Latitude	Longitude
39.72149	-87.69682

Site name / code: Willow Creek lawn / willowlawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
39.72086	-87.69635

Property name: Wolf Creek State Park
Three sites (plus one discarded)

Site name / code: Wolf 1 / wolf1
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Mowing, prescribed burn every 2 years, invasive control with herbicide

Years surveyed:
2020, 2022

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, A. hirtella, A. incarnata*, *A. purpurascens*
Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.50172	-88.68235

Approximate milkweed planting coordinates:

Latitude	Longitude
39.5012	-88.68137

Site name / code: Wolf 2 / wolf2
Site type: Prairie restoration
Coarse classification: Restoration

Known management actions: Mowing, prescribed burn every 2 years, invasive control with herbicide

Years surveyed:
2020, 2021

Included in:
Milkweed plantings
Floral surveys
Milkweed density estimates, monarch ovipostion rates

Milkweed species observed: *A. syriaca, C. laeve*

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.49101	-88.68007

Approximate milkweed planting coordinates:

Latitude	Longitude
39.4911	-88.68145

Site name / code: Wolf 3 / wolf3
Site type: Old field
Coarse classification: Hay/old field

Known management actions: Unknown

Floral survey and milkweed density estimate coordinates:

Latitude	Longitude
39.48332	-88.68494

Notes: Surveyed once in 2020, overgrown with shrubs, determined to be a shrubland instead of grassland, discontinued from project and data collection

Site name / code: Wolf lawn / wolflawn
Site type: Lawn
Coarse classification: Lawn

Year surveyed:
2020, 2021, 2022

Included in:
Milkweed plantings

Approximate milkweed planting coordinates:

Latitude	Longitude
39.48416	-88.68501

Appendix 2

Metadata for Supplementary Data Sets

Supplementary Data Set 1

Title: Blooming Species Records and Abundances on Illinois DNR Properties

File name: dataset1_objective1_bloomingSpp.csv

Description:

These data were collected from 49 study sites on 29 Illinois Department of Natural Resources properties. The sites were visited a mean of five times in 2020, 2021, and 2022. Most sites were visited in two different years. Visits occurred in three 'rounds', either in early summer (typically late May and June), middle summer (July and early August), or late summer (mid-August to mid-September). Data on blooming species abundances were collected using the Integrated Monarch Monitoring Protocol, published by Monarch Joint Venture (2021). The presence of open flowers of blooming plant species (those that may attract floral visitors to aid in pollination) were recorded in 100 quadrats along a 500 meter transect.

Some plant species identifications were uncertain. In particular, at some sites *Heterotheca subaxillaris* and *Chrysopsis camporum* (aka *Heterotheca camporum*) were identified in alternating visits. For this data set all of those records were changed to *C. camporum*, although a closer inspection may be worthwhile.

The file format is comma-separated values (CSV). Each row represents a single record for a plant species, during a single visit to a site. Data are sorted by site code (alphabetical), then year (ascending), then round of sampling (ascending), then abundance (quadrat.count) of a given species (descending). Column definitions follow:

‘site’ – The code for a given site. The information associated with each site can be found in Appendix 1.

‘property’ – The Illinois DNR property where the study site is found.

‘round’ – The sampling round, which ranges from one to three. Earlier rounds are earlier in the season. No data were collected during round 1 in 2020.

‘year’ – The year of data collection for a given record (2020 to 2022).

‘month’ – The numeric month of data collection for a given record (between May and September, or 5 and 9).

‘day’ – The day of the month of data collection for a given record.

‘species’ – The scientific name of the species recorded. Nomenclature generally follows the USDA PLANTS Database (USDA-NRCS 2022). When no blooming species were recorded, ‘None’ is entered under this column.

‘quadrat.count’ – The number of quadrats (out of 100) that the species was observed in during a single site visit. When no blooming species were recorded, a value of zero is recorded in this column along with the ‘None’ in the ‘species’ column.

‘species.commonname’ – Combined scientific and common names, included for easy reference only. The common name used may not be universally used, and it may not be consistent across records. The scientific name under the ‘species’ column is more reliable for consistency.

References:

Monarch Joint Venture. 2021. Integrated Monarch Monitoring Program. Version 3.1. URL: https://monarchjointventure.org/images/uploads/documents/IMMP_Guidebook_2022_FINAL.pdf

USDA, NRCS. 2022. The PLANTS Database. National Plant Data Team, Greensboro, NC USA. URL: http://plants.usda.gov

Supplementary Data Set 2

Title: Blooming Species Lists and Estimates of Abundance on DNR Properties, June 2022

File name: dataset2_objective1_floralEstimatesJun2020.csv

Description:

These data were collected from 22 study sites on 12 Illinois Department of Natural Resources properties. The sites were visited once during June 2020. Estimates of blooming plant species abundance were made. Blooming plants were treated as those that may attract floral visitors to aid in pollination. These data are in the place of the first round of sampling for 2020, when quantitative data collection could not occur due to delays and restrictions associated with the Covid-19 pandemic.

The file format is comma-separated values (CSV). Each row represents a single record for a plant species at a single site. Data are sorted by the site code (alphabetically) and the estimated abundance of each species (descending). Column definitions follow:

‘site’ – The code for a given site. The information associated with each site can be found in Appendix 1.

‘property’ – The Illinois DNR property where the study site is found.

‘year’ – The year of data collection for a given record (2020).

‘month’ – The numeric month of data collection for a given record (June, or 6).

‘day’ – The day of the month of data collection for a given record.

‘species.commonname’ – Combined scientific and common names, generally following the nomenclature of the USDA PLANTS database (USDA-NRCS 2022).

‘estimated.count’ – The estimated number of open flowers in the area that was expected to become the plot area. Estimates were put on an approximately logarithmic scale, selecting a value among 1, 3, 10, 30, 100, 300, 1000, 3000, etc.

References:

USDA, NRCS. 2022. The PLANTS Database. National Plant Data Team, Greensboro, NC USA. URL: http://plants.usda.gov

Supplementary Data Set 3

Title: Summary statistics for blooming species recorded during quantitative floral surveys

File name: dataset3_objective1_summaryFloralResources.csv

Description:

Summary of floral abundance data collected from 49 study sites on 29 Illinois Department of Natural Resources properties. Measures of floral abundance and diversity are summarized here. See Data Set 1 for the underlying data and further details. The sites were visited a mean of five times in 2020, 2021, and 2022. Most sites were visited in two different years. Visits occurred in three 'rounds', either in early summer (typically late May and June), middle summer (July and early August), or late summer (mid-August to mid-September). Data were collected in 100 quadrats along a 500-meter transect using the Integrated Monarch Monitoring Protocol (Monarch Joint Venture 2021).

The file format is comma-separated values (CSV). Each row represents a record for a single visit to a single site. Data are sorted by the site code (alphabetically), year (ascending), and round of sampling (ascending). Column definitions follow:

'site' – The code for a given site. The information associated with each site can be found in Appendix 1.

'round' – The sampling round, which ranges from one to three. Earlier rounds are earlier in the season. No data were collected during round 1 in 2020.

'year' – The year of data collection for a given record (2020 to 2022).

'month' – The numeric month of data collection for a given record (between May and September, or 5 and 9).

‘day’ – The day of the month of data collection for a given record.

‘spp.quad.sum’ – The sum of the number of quadrats recorded for all species during a single visit.

‘diversity’ – The inverse Simpson’s Index, also known as the effective number of types.

‘quads.with.blooms’ – The number quadrats (out of 100) observed during the visit that contained an open flower from a species that depends on insect pollinators. This measure of floral abundance was not used in statistical analyses and summaries presented above, but is provided for reference.

‘richness’ – The number of blooming species observed in quadrats during the visit. This coarse measure of diversity was not used in statistical analyses and summaries presented above, but is provided for reference.

References:

Monarch Joint Venture. 2021. Integrated Monarch Monitoring Program. Version 3.1. URL: https://monarchjointventure.org/images/uploads/documents/IMMP_Guidebook_2022_FINAL.pdf

Supplementary Data Set 4

Title: Lists of floral visitors to plant species recorded by the Critical Trends Assessment Program

File name: dataset4_objective1_ctapSppVisitors.csv

Description:

We searched the literature to find floral visitors to plant species encountered during vegetation surveys by the Critical Trends Assessment Program (CTAP). For each species, we have a brief summary of what was found in the literature, and whether each of three insect guilds are known to visit the flowers of the plant species. The three guilds of insects are bees, lepidopterans, and beetles.

The file format is comma-separated values (CSV). Each row represents a single plant species from the CTAP data. Data are sorted by the species name (alphabetically). Column definitions follow:

‘plant.species’ – The scientific name of a plant species encountered by CTAP. Nomenclature follows Mohlenbrock (1986), as this is the reference used by CTAP botanists.

‘visitor.details’ – A brief summary of the floral visitors found in the literature for the CTAP plant species. Plant species which are not known to have floral visitors are included for reference. In some cases wind-pollination was assigned by personal knowledge of the floral structure and comparison to related species (e.g., members of *Carex*).

‘bee’ – TRUE or FALSE, giving whether the floral visitors found in the literature include bees of any type.

‘lepidopteran’ – TRUE of FALSE, giving whether the floral visitors found in the literature include lepidopterans of any type.

‘beetle’ – TRUE or FALSE, giving whether the floral visitors found in the literature include beetles of any type.

‘fly’ – TRUE of FALSE, giving wehther the floral visitors found in the literature include flies and other dipterans of any type. Note that we did not analyze trends for ‘fly’ plants in this report.

References:

Mohlenbrock RH. 1986. Guide to the Vascular Flora of Illinois. Southern Illinois University Press