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Urban Ecosystems

ISSN 1083-8155
Volume 22
Number 6

Urban Ecosyst (2019) 22:1083-1096
DOI 10.1007/s11252-019-00880-8

Springer

Urban Ecosystems (2019) 22:1083–1096
https://doi.org/10.1007/s11252-019-00880-8

Characterizing urban butterfly populations: the case for purposive point-count surveys

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Published online: 9 July 2019

Abstract

Developing effective butterfly monitoring strategies is key to understanding how butterflies interact with urban environments, and, in turn, to developing local conservation practices. We investigated two urban habitat types (public gardens and restored/reconstructed prairies) and compared three survey methods (Pollard transects, purposive point counts, and random point counts) to determine which was most productive for detecting butterflies and assessing family diversity. We conducted 66 butterfly surveys by using each method (198 total) from May through September in 2015 and 2016 at six sites (three public gardens and three prairies) in Ames, Ankeny and Des Moines, Iowa. All survey methods were used on 11 sampling dates at each site. Overall, we observed 2,227 butterflies representing 38 species: 1,076 in public gardens and 1,151 in prairie areas. We used a smaller data set standardized for survey effort, including 1,361 of these sightings, to compare survey methods and habitat types. Although there were no significant differences in number of butterfly sightings between the two habitats, more sightings (798) were documented by using purposive point counts when compared to Pollard transects (297) or random point counts (266) (for both comparisons, $p < 0.0001$). Occupancy modeling also indicated that purposive point counts were most effective in detecting certain species of butterflies, most notably those within the Pieridae (whites, sulphurs) and Papilionidae (swallowtails). We conclude that public gardens and restored/reconstructed prairies in urban settings can provide important butterfly habitat, and that purposive point-count surveys are most effective for detecting butterflies in these relatively small-scale landscape features.

Keywords Urban butterfly habitat · Public gardens · Restored urban prairies · Butterfly survey methods · Pollard transects · Occupancy modeling for butterflies

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11252-019-00880-8) contains supplementary material, which is available to authorized users.

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Introduction

Steady declines in pollinator populations have recently generated much concern. For Lepidoptera (a group for which data are generally available), surveys indicate a global decline in abundance of 35% over the past 40 years (Dirzo et al. 2014). Intensive agricultural practices and urban expansion have been suggested to be among the primary causes of declines in butterfly abundance and diversity (Maes and Van Dyck 2001; Van Dyck et al. 2009; Dennis et al. 2017). Some reports indicate that native invertebrate diversity generally decreases with increased urbanization (e.g., McKinney 2008; Matteson and Langellotto 2010; Concepción et al. 2015). However, depending on habitat suitability in the surrounding matrix, some urban habitats may provide refugia and increase local butterfly abundance and/or species richness (Bolund and Hunhammar 1999; Kadlec et al.

2008; Panzer et al. 2010). This has led to increased interest in creating suitable habitats for butterflies in urban areas, and to programs at continental, national and local scales to support creation of butterfly habitat (e.g., the North American Butterfly Association's Butterfly Garden and Habitat Program, and the National Pollinator Garden Network's Million Pollinator Garden Challenge™). These initiatives focus on educating individual landowners about butterfly species and providing resources to guide planting and management of gardens for pollinator use (see, for example, http://nababutterfly.com/; http://millionpollinatorgardens.org/).

The potential for urban areas to provide habitat for butterflies has also led to increased interest in documenting and assessing butterfly use of these areas (e.g., Giuliano et al. 2004; Di Mauro et al. 2007; Matteson and Langellotto 2010; Matteson et al. 2013; Concepción et al. 2016). These studies have focused on two key subjects for urban butterfly conservation: 1) effects of urban habitats (community gardens, public gardens, or urban natural areas) on butterfly populations and species richness (Giuliano et al. 2004) and 2) effects of the urban matrix (pavement, buildings, cars, and people) on butterfly movement among appropriate habitat patches (Matteson and Langellotto 2010). Effectively conducting such assessments is key to understanding how to design and manage urban landscapes for butterfly use (e.g., presence, movement across the landscape, floral visitation, oviposition).

Although it is possible that urban gardens and small, embedded natural areas within urban landscapes offer habitat suitable for butterflies (at a minimum for movement across larger landscapes), relatively few studies have directly compared butterfly use of different types of potentially valuable urban habitats – e.g., large public garden and native landscaping installations. Thus, information about butterfly use of these potential habitats would be useful to increase the effectiveness of future efforts to create the most suitable urban-embedded habitat areas. Additionally, such analyses should be place-based, to account for factors specific to urban areas, such as smaller habitat areas and increased human presence and activities (Menninger and Palmer 2006). Finally, such studies should include estimates of detection probability and deliberate design that lends itself to replication to contribute most strongly to advances in knowledge and conservation of butterflies (Kral et al. 2018).

A commonly used survey method to monitor butterflies is the Pollard transect (Pollard 1977; Pollard and Yates 1994; Brown and Boyce 1998), originally proposed as a protocol to standardize butterfly observations. This method involves traversing the same fixed path at a constant rate at regular intervals (e.g., weekly) during the survey season and counting butterflies within a defined area relative to the path of the observer. Although use of a standard protocol should allow comparability of data across projects, this method has often been modified to be more applicable to the particular habitats under study (Yahner 2001; Collinge et al. 2003; Clark et al. 2007; Kral et al. 2018). In fact, the standard Pollard transect may not be very suitable for use in many urban landscapes where floral resources are generally more limited and widely dispersed than would be typical in natural areas.

Alternative methods that have been used, less systematically, are variations of point-count sampling (Van Swaay et al. 2012; Henry et al. 2015). Point counts are conducted by documenting all butterflies within a specified (usually circular/spherical) area at a single location over a certain time interval. In their study of the Miami blue butterfly (*Cyclargus thomasi bethunebakeri*), Henry et al. (2015) used modified point counts to focus survey efforts on a particular host plant and habitat configuration known to be used by the Miami blue. Thus, point counts allowed surveyors to apply their knowledge and experience to focus monitoring efforts on specific areas that butterflies were likely to use.

In addition to choice of survey method, survey success (detection of butterflies) may also be partially dependent on species behavior (Isaac et al. 2011). Species within different butterfly families exhibit diverse foraging, basking and courting strategies. For example, among several species in the Hesperiidae (skippers), male butterflies perch in vegetation and dart at passing objects in their search for females (Scott 1973). This is in contrast to many species in the Nymphalidae (brush-footed butterflies), where males patrol continuously to search for females (Bitzer and Shaw 1979; Alcock 1994). These variations in behavior may lead to differences in observations based on the survey method used. For example, during a Pollard transect, an observer's movement may cause perching male skippers to take flight, increasing the probability of detection. However, skippers also tend to be small, blend in well with their surroundings, and are difficult to detect when perching, so they could be missed in point-count surveys (Carneiro et al. 2014). In contrast, larger and more colorful butterflies (e.g., the Nymphalidae) are more likely to be observed regardless of survey method.

Previous studies conducted even in relatively large natural areas have shown that data collected by using Pollard transects may not accurately reflect either butterfly abundance or species richness (Collier et al. 2006; Pellet 2008; Isaac et al. 2011). In particular, researchers have found that detection estimates generated from Pollard transects are low if relatively few transects are performed at a site (Kéry and Plattner 2007; Isaac et al. 2011). One recommendation offered by Kéry and Plattner (2007) was that at least 20 Pollard transects would be necessary on a given site in order to correctly determine if a species is or is not present.

In the Midwest United States specifically, data point toward general declines in pollinators and butterfly populations (Cameron et al. 2011; Swengel et al. 2011). The predominantly agricultural landscape matrix of the Midwest contains fewer remnants of natural vegetation communities (prairies, wetlands, or forests; Gallant et al. 2011) than most ecoregions, with correspondingly smaller native host-plant populations and limited habitat for native wildlife species, including butterflies (Debinski and Kelly 1998; Hartzler and Buhler 2000).

In Iowa, there have been several recent studies that characterized butterfly populations in rural parks, preserves and grassland management areas (Vogel et al. 2010; Moranz et al. 2012; Delaney et al. 2015), roadsides and crop buffers (Ries et al. 2001; Reeder et al. 2005; Shepherd and Debinski 2005), and experimental prairie plantings (Myers et al. 2012). However, we are not aware of previous studies focused on butterfly populations in the urban areas of this region. Because of strong interest in providing additional butterfly habitat in cities throughout Iowa (programs such as Blank Park Zoo's *Plant. Grow. Fly*), we chose to examine butterfly populations in potential habitats that already exist in three central Iowa municipalities. Our objectives were to determine the level of butterfly use of different urban habitat types and the effectiveness of three different survey protocols to detect them. Specifically, we investigated the following questions:

1. How many and what species of butterflies are present in urban areas within the predominantly agricultural landscape matrix of central Iowa? Are there differences in the number and species of butterflies visiting public gardens and restored prairie areas in these urban settings?
2. Does survey method influence our ability to detect butterflies in these areas?

Methods

Study area

We conducted this study in central Iowa, situated in the heart of the Corn Belt region of the U.S.A. (NOAA 2017). This is a landscape dominated by intensive row-crop agriculture systems surrounding steadily expanding urban and exurban areas (ISU Extension 2016). Both intensive landscape alterations and management regimens used in them (e.g., widespread use of pesticides) have made this landscape less and less hospitable for butterflies, especially since the early 1990s (Hartzler 2010). Within this overall landscape context, public gardens (manicured areas with abundant and concentrated floral resources) and restored prairies (reconstructed by using mixtures of regionally native grasses and forbs endemic to the region) are being promoted and used to provide potential habitat for pollinators, including butterflies.

Study sites

We monitored six sites in Ames, Ankeny and Des Moines in central Iowa: three public gardens and three restored/reconstructed prairie areas (Fig. 1). The three public garden sites include the northern section of Reiman Gardens (a 2.5-ha portion of a 6.6 ha public garden located in Ames); the Greater Des Moines Botanical Garden (a 1.1 ha public garden in Des Moines); and the Clare and Miles Mills Rose Garden (a 2.3 ha public garden also located in Des Moines). The urban prairie sites include the Pohl Prairie Preserve at Ames High School (a 2.2-ha portion of a 6.1 ha restored remnant prairie located in Ames); Ada Hayden Heritage Park (a 2.4-ha area of reconstructed prairie in a 157.1 ha park located in Ames); and the grounds of the Iowa Association of Municipal Utilities (a 1.9 ha reconstructed prairie in Ankeny).

Public gardens are designed to showcase a variety of ornamental plants, often emphasizing cultivars of both native and non-native flowering plants. The public gardens included in this study were characterized by areas of densely planted annual and perennial flowering plants, such as common lilac (*Syringa vulgaris*), calamint (*Calamintha nepeta*), smooth hydrangea (*Hydrangea arborescens*), meadow sage (*Salvia nemorosa*), yarrow (*Achillea millefolium*), and Culver's root (*Veronicastrum virginicum*), as well as several cultivars of rose (*Rosa* spp.), peony (*Paeonia* spp.), petunia (*Petunia* spp.), cock's comb (*Celosia* spp.) and begonia (*Begonia* spp.). These floral collections were all located in areas separated by manicured lawn spaces. All three public garden sites included in this study are designed and managed to encourage human visitation and are often used for large public events.

Prairie restorations/reconstructions are frequently established along roadsides and in parks as a relatively low-maintenance land cover that contains species historically widespread throughout the landscape (Houseal and Smith 2000). In urban settings, similar prairie reconstructions are used in open areas along the borders of parks or as part of larger commercial landscapes. The prairie areas included in this study were located in areas of less intense human activity as compared to the public gardens. These areas included evenly distributed native grasses, such as big bluestem (*Andropogon gerardii*), sideoats grama (*Bouteloua curtipendula*), and Indian grass (*Sorghastrum nutans*), mixed with native forb species, such as bee balm (*Monarda fistulosa*), false sunflower (*Heliopsis helianthoides*), gray-headed coneflower (*Ratibida pinnata*), Canada goldenrod (*Solidago canadensis*), compass plant (*Silphium laciniatum*), and common milkweed (*Asclepias syriaca*).

Survey methods

We surveyed each site at approximately 2-week intervals, including six times in 2015 and five times in 2016, between late May and late September using the same level of survey effort at all sites. We used modified Pollard transects and two point-count survey methods (purposive and random) to detect and quantify butterflies at each site. We described species detected, transect section, and butterfly activities at the time of

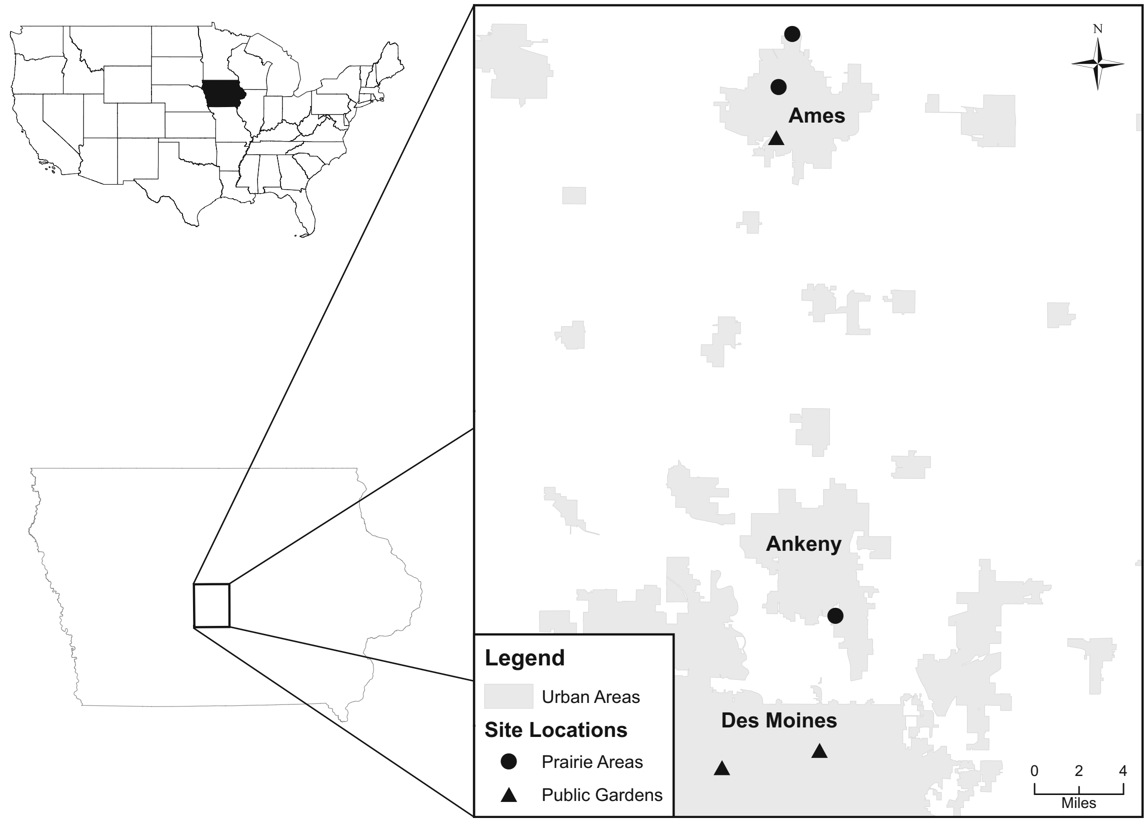

Fig. 1 Six sites (three public gardens and three restored/reconstructed prairies) where butterfly surveys were conducted. Sites were located in Ames, Ankeny, and Des Moines, central Iowa, U.S.A.

observation (as per IDNR 2006). Surveys were conducted between 1000 and 1830 on sunny days, with wind speeds <16 km per hour and temperatures between 21° and 35 °C (Ries et al. 2001; IDNR 2007). We conducted one 200-m Pollard transect survey, 12 purposive point counts, and 12 random point counts at each site for each sample date.

For modified Pollard transects, the senior author (BJL) established single, straight 5-m-wide, 200-m-long transects, or two 100-m-long transects (to fit the site) marked with regularly spaced flags. The senior author and a second observer walked transects at a speed of 10 m per minute and recorded butterflies observed within 2.5 m on either side and 5 m in front of the observer (Pollard 1977; Pollard and Yates 1994; Ries et al. 2001). For all point-count surveys, the same two observers stood back-to-back at each point, and identified and recorded butterflies seen within a semi-spherical area within a 5-m radius during a 5-min period.

For purposive point-count surveys, there were no fixed starting or observation points: the observers meandered throughout each site on each date to identify locations where butterflies were present or that were judged to have high potential for butterfly use based on floral resources, then marked each location and conducted a point count. For random point-count surveys, the senior author used the random point function in ArcMap 10 (ESRI 2015, 2016) at the beginning of each field season to generate a set of fixed points within each site that were marked and used for the entirety of that season.

During each survey, field observers identified butterflies to species (nomenclature follows Schlicht et al. 2007) and classified them as habitat generalists or habitat specialists (as per Vogel et al. 2010). Observers also identified characteristics of vegetation (number of species, species in flower, percent floral area) along each transect and at each sample point (Ries et al. 2001; Matteson and Langellotto 2010). A hand-held Android device with the "Unified Butterfly Recorder" (http://www.reimangardens.com/collections/insects/unified-butterfly-recorder-app/) application was used to collect and organize all butterfly survey data. Butterflies that could not be readily identified in the field were photographed for later consultation with experts. Butterflies that remained unidentified after multiple consultations or that could not be photographed in the field were recorded as unidentified. These data (accounting for 3% of all observations) were included in the total numbers of butterfly sightings for survey comparisons but not for species richness or occupancy model analyses.

Overview of data analyses

We determined the total number of individual sightings and number of species observed for each of the three survey methods and each site for all sample dates. We also determined the total number of habitat-specialist species and species of special concern for site and survey method. We then standardized the number of sightings to allow comparisons of the three survey methods by setting a limit of equivalent survey effort for total time elapsed (19 min for each survey method at each site) and area surveyed (950 m^2). To do this, we included only observations that took place in the first 190 m of each Pollard transect and the first 95 s of each purposive and random point count. The standardized data were used for comparing the total number of observations when using each survey method as well as for each survey method within each habitat type. The standardized data were also used for occupancy modeling (as described below).

Statistical methods

For the dataset containing all sightings, we used an analysis of variance (ANOVA; SAS 2017) to compare the number of observations of habitat-specialist species in each habitat type. We applied a general linear mixed model (PROC GLIMMIX) to compare mean number of all butterfly observations for both habitat types and survey methods (SAS Version 9.4, SAS Institute Inc., Cary NC, USA). We used a Poisson distribution to correct for unevenly distributed survey data (Stigler 1982). The overall type III F-test for each fixed effect was followed up by pairwise comparisons of least square means using Tukey's HSD to adjust for multiple comparisons (SAS 2017). We declared significance at $p < 0.05$. Categorical variables included in the model were date, site, survey method, and habitat type. Fixed effects in the model included survey date, survey method, and habitat type. There was considerable variability in the number of sightings at each site over time. By treating survey date as a fixed effect, this forced the comparisons between survey methods to be made within a specific day. Random effects included site (for each habitat type) and the interaction of date, survey method, and site for each habitat type.

Occupancy modeling

We constructed models in R Version 3.0.2 (R Core Team 2013) with the RMark package (Laake 2013) to estimate occupancy and detection probabilities for each lepidopteran family by survey method and habitat type. We also used these models to determine importance values for survey year and habitat type related to occupancy, and for habitat type and survey method related to detection. Occupancy models contain two components: an estimate of occupancy (Ψ), the probability that a species is occupying a site, and an estimate of detectability (p_j), the probability that a species will be detected if they do occupy a site (MacKenzie et al. 2002).

We first developed occupancy models for individual species, using only the 25 species observed more than five times, based on preliminary analysis of species-specific occupancy models, which indicated that survey method and habitat type became important determinants in models with more than five observations. We developed a set of 12 models for each species, including all combinations of variables (survey method, habitat type, and year). We then combined the models for all species within a family group to create composite models for each of the five families represented by the species in our dataset.

Model selection We tested the family models by using site- and survey-specific variables. For occupancy (Ψ), we investigated survey year and habitat type. For detection estimates (p_j), we investigated habitat type and survey method. The relative quality of each family model was measured by using the Akaike information criterion (AIC; Akaike 1974), averaging AIC and ΔAIC for each species included in a family model. Average scores for ΔAIC were re-scaled so that the lowest average was equal to zero allowing us to standardize model selection criteria. We chose models based on two criteria: 1) the detection (p_j) component of the model included survey method and habitat type as variables, and 2) the model was within two ΔAIC of the best fitting model (Burnham and Anderson 2002).

Detection estimates and importance values The occupancy models we selected provided family-level detection assessments for habitat type and survey method. Detection histories for each family were collated as a binary variable within each year for habitat type and survey method (1 = at least one butterfly in a family was observed, and 0 = no butterfly in that family was observed). Survey year was also recorded and used to determine importance values for occupancy. Detection probabilities were calculated by estimating occupancy rates with detection probabilities <1.0, as described by MacKenzie et al. (2002). We calculated 95% confidence intervals with R (R Core Team 2013) to determine differences among detection estimates for habitat types and survey methods. To assess the relative importance of different model variables, we summed the Akaike weights (w_i) for each model in which the variable of interest occurred (Wagenmakers and Farrell 2004).

Results

Survey observations

We conducted 198 surveys (66 using each method) during the 2 years of observations. We detected 2,227 butterflies representing 38 known species (some skippers were identified only to family) and five families (Table 1 and Appendix A). Of these, 332 butterflies representing 24 species were

Table 1 Numbers and proportions of all butterfly sightings by habitat type (public gardens and prairie areas) and survey method (Pollard transects, purposive, and random point-count surveys). Butterfly surveys were conducted approximately every 2 weeks at six sites in Ames, Ankeny, and Des Moines, central Iowa, between late May and late September, 2015 and 2016

	Public gardens		Prairie areas		Combined
Survey method	Number of sightings	Percent of garden sightings	Number of sightings	Percent of prairie sightings	Number of all sightings
Pollard transects	125	11.6	207	18.0	332
Purposive point counts	687	63.8	629	54.6	1316
Random point counts	264	24.5	315	27.4	579
Total taxa[a] observed	34	89.4	29	76.3	38
All sightings	1076	48.4	1151	51.6	2227

[a] Some skippers were not identified to species

observed with Pollard transects; 1,316 butterflies representing 38 species resulted from purposive point counts; and 579 butterflies representing 30 species resulted from random point counts. Habitat-specialist species (Vogel et al. 2010) accounted for 88 (4%) of our sightings (Table 2).

Comparison of habitat types

We observed a total of 1,076 butterflies in public gardens and 1,151 in restored prairies (Table 1). No significant difference in the total number of butterflies was detected between the two habitat types ($p = 0.58$, $t = 0.61$, $df = 3.93$). Several species were observed only in public gardens: checkered white (*Pontia protodice*), cloudless sulphur (*Phoebis sennae*), common checkered-skipper (*Pyrgus communis*), coral hairstreak (*Satyrium titus*), crossline skipper (*Polites origenes*), hackberry emperor (*Asterocampa celtis*), red-spotted purple (*Limenitis arthemis arthemis*), regal fritillary (*Speyeria idalia*), and wild indigo duskywing (*Erynnis baptisiae*). Those observed only in prairie areas included bronze copper (*Lycaena hyllus*), giant swallowtail (*Papilio crephontes*), little wood satyr (*Megisto cymela*), and silvery checkerspot (*Chlosyne nycteis*) (Appendix A).

There was no significant difference in the number of observations of habitat-specialist species between the two habitat types ($p = 0.14$, $F = 2.47$, $df = 14$). Although we documented only a third as many sightings of habitat specialists in public gardens (21) compared to prairie areas (67), we did note a larger number of habitat-specialist taxa in public gardens (7) than in prairie areas (5) (Table 2). Bronze copper, great spangled fritillary and viceroy were among species detected more frequently in prairie areas. However, habitat-specialist species in the family Hesperiidae (crossline skipper and Delaware skipper) were observed more often in gardens (7 sightings) than in prairie areas (5 sightings).

Comparison of survey methods

The standardized dataset (equivalent survey time and area) included 1,361 butterflies representing 38 known species

Table 2 All habitat-specialist species (classified as per Vogel et al. 2010) and species of special concern (denoted with an asterisk, classified as per IDNR 2007) observed using three survey methods at six study sites (three public gardens and three restored prairie areas) during summer 2015 and 2016

		Habitat Type		
Species (common name)	Species (scientific name)	Public gardens	Prairie areas	Total
Bronze copper	*Lycaena hyllus*	0	17	17
Coral hairstreak	*Satyrium titus*	1	0	1
Crossline skipper	*Polites origenes*	4	0	4
Delaware skipper	*Anatrytone logan*	3	5	8
Gray copper	*Lycaena dione*	1	3	4
Great spangled fritillary	*Speyeria cybele*	10	25	35
Regal fritillary*	*Speyeria idalia*	1	0	1
Viceroy	*Limenitis archippus*	1	17	18
Wild indigo duskywing*	*Erynnis baptisiae*	2	0	2
Total sightings		23	67	90

and five families. Of these, 297 butterflies were observed by using Pollard transects, 798 by using purposive point surveys, and 266 by using random point surveys. Overall, purposive point surveys generated a greater number of sightings than did Pollard transects ($p < 0.0001$; Table 3) or random point surveys ($p < 0.0001$; also Table 3). There was no significant difference in the number of sightings between Pollard transects and random point surveys ($p = 0.46$, Table 3).

The standardized dataset included 702 sightings in gardens and 659 in prairies. While using Pollard transects, we observed 109 butterflies in public gardens and 188 in prairie areas. Purposive point-count surveys included 456 sightings in gardens and 342 in prairies, and random point counts included 137 sightings in gardens and 129 in prairie areas. Within habitat types, purposive point surveys also generated more sightings than did either Pollard transects or random point surveys in both gardens and prairie areas ($p < 0.0001$; Table 4). However, there were no significant differences in the number of sightings in either gardens or prairies when Pollard transects were compared to random point surveys ($p = 0.69$ and $p = 0.23$, respectively; Table 4).

Occupancy modeling

Model selection At least one model that we generated met our selection criteria for four families: Lycaenidae (gossamer-winged butterflies), Nymphalidae (brush-footed butterflies), Papilionidae (swallowtails), and Pieridae (whites and sulphurs) (Table 5). We did not generate any models that met our criteria for the Hesperiidae (skippers) (none was within two ΔAIC of its best fitting model). For each of the remaining four families, there was one model that met both model selection criteria: p (~Survey + Environ)Ψ(~1). This was the best model for the Lycaenidae, Papilionidae, and Pieridae, and was 1.63 ΔAIC from the best model for the Nymphalidae.

Detection estimates and importance values We were able to produce detection estimates for the Lycaenidae, Nymphalidae, Papilionidae, and Pieridae. Detection estimates indicated that there was a significant difference (based on non-overlapping 95% confidence intervals, Table 6) between purposive point counts and random point counts in both garden and prairie areas for the Pieridae. There were no significant differences in detection estimates between any of the other survey-method and habitat-type combinations, although the number of sightings generated by using purposive point counts was consistently higher than those for the other methods (Table 6). Detection estimates were particularly high for the Pieridae based on purposive point surveys (0.88 in both gardens and prairies) and low for the Papilionidae based on Pollard transects (0.07 in gardens and 0.03 in prairies). Detection estimates were also significantly lower for the Papilionidae than for the other three families across all survey types in both habitats (again, based on non-overlapping 95% confidence intervals per Table 6).

To predict occupancy for species in the Hesperiidae, Nymphalidae, Papilionidae, and Pieridae, habitat type importance values were relatively low (Table 7). However, habitat type was important for the Lycaenidae. Survey year influenced only one family, the Hesperiidae (most likely due to less experience identifying species within this family during the first year). For detection, importance values indicated that habitat type was generally more important than was survey method for all families except the Papilionidae. Habitat type was especially important for detection of butterflies in the Pieridae (importance value of 1.00).

Discussion

Understanding the influence of habitat type on site occupancy and population size is crucial for conservation management. For population monitoring, different survey methods may affect the ability to detect butterflies in particular habitat types. Here, we evaluated the number of butterflies observed, as well as the number of species present, in public gardens and restored prairies in urban areas. We used three survey methods to determine the number of butterflies and the number of species present on the different site types and to assess whether there were differences in detection ability. Based on data standardized for equivalent survey effort, there were no significant differences in the number of butterfly sightings between habitat types, although we did detect more butterflies in both habitats when using purposive point counts as compared to modified Pollard

Table 3 Comparison of standardized number of butterfly sightings made by using Pollard transects, purposive point counts, and random point counts at six sites in Central Iowa during summer 2015 and 2016. Means represent the average number of butterflies observed during a single survey at a site. All pairs' analysis of variance (ANOVA) comparisons were based on Tukey's honest significant difference (HSD) to detect differences among survey methods

Survey method 1	Mean	Survey method 2	Mean	Mean difference	Standard error	p value	t	df
Pollard transect	4.50	Purposive point count	12.09	−7.59	0.11	< 0.0001	−14.37	191
Pollard transect	4.50	Random point count	4.03	0.47	0.12	0.46	1.84	191
Purposive point count	12.09	Random point count	4.03	8.06	0.12	< 0.0001	15.79	191

Table 4 Comparison of standardized number of butterfly sightings made by using Pollard transects, purposive-point counts, and random-point counts in public garden and restored prairie habitat types. Means represent the average number of butterflies observed in each habitat type during a single survey at a site. All pairs' analysis of variance (ANOVA) comparisons were based on Tukey's honest significant difference (HSD) to detect differences among survey methods within each habitat

Habitat type	Survey method 1	Mean	SE	Survey method 2	Mean	SE	Mean diff.	SE diff.	*p* value	t	df
Public gardens	Pollard transect	3.30	0.39	Purposive point count	13.81	0.38	−10.51	0.16	< 0.0001	−12.58	191
Public gardens	Pollard transect	3.30	0.39	Random point count	4.15	0.38	−0.85	0.18	0.69	0.41	191
Public gardens	Purposive point count	13.81	0.38	Random point count	4.15	0.38	9.66	0.16	< 0.0001	12.82	191
Prairie areas	Pollard transect	5.70	0.38	Purposive point count	10.36	0.37	−4.66	0.15	<0.0001	−7.48	191
Prairie areas	Pollard transect	5.70	0.38	Random point count	3.91	0.38	1.79	0.16	0.23	1.19	191
Prairie areas	Purposive point count	10.36	0.39	Random point count	3.91	0.38	6.45	0.15	< 0.0001	9.45	191

transects or random point counts. The survey method used, in any case, should depend on the purpose of the study.

Survey observations

The total number of butterflies we observed (2,227) in our urban surveys was similar to previous butterfly surveys conducted in rural Iowa, although we acknowledge these studies were conducted over different timespans and for other specific purposes. For example, Myers et al. (2012) observed 2,110 butterflies, Vogel et al. (2010) observed 2,779 butterflies, and Shepherd and Debinski (2005) observed 1,314 butterflies in their earlier studies. Although we observed comparable numbers of butterflies in our surveys of both types of urban habitats, the number of butterflies was low when corrected for equivalent survey effort (e.g., number of butterflies encountered per minute of surveying or per m of transect distance) in relation to several previous surveys conducted in rural areas of Iowa. For example, we detected an average of 0.36 butterflies per minute in urban habitats, as compared to 0.83 per minute observed in rural roadside prairies (Ries et al. 2001), 0.88 per minute in recently established experimental prairie plantings (Myers et al. 2012), or 1.75 per minute in preserved prairie remnants (Vogel et al. 2010). This is consistent with other studies in which investigators directly compared butterfly populations along transects extending from rural to urban areas and found fewer in urban settings (e.g., Blair 1999; Di Mauro et al. 2007). However, it is also the case that general declines in butterfly populations have been observed both globally (Dirzo et al. 2014; Dennis et al. 2017) and in the Midwest (Cameron et al. 2011; Swengel et al. 2011) since at least the early 1990s, which may affect the comparability of our surveys with the earliest of those identified above.

The number of butterfly taxa we observed (38) was somewhat greater than previous surveys in rural areas (e.g., 25 species observed by Ries et al. 2001, 37 species recorded by Shepherd and Debinski 2005; and 31 species noted in Myers et al. 2012). Although in some instances these earlier studies were conducted during a shorter interval, this number of taxa is somewhat surprising given findings of other researchers who concluded that urban areas were characterized by lower species richness (e.g., Hardy and Dennis 1999; Yahner 2001; Stefanescu et al. 2004; Posa and Sodhi 2006; Clark et al. 2007). There were seven habitat-specialist species (Vogel et al. 2010) and two species of special concern (IDNR 2007) among the taxa we observed, but they accounted for a relatively small proportion of all observations (4%) compared to earlier surveys (e.g., 32% for Ries et al. 2001 and 50% for Vogel et al. 2010). The presence of two species of special concern (regal fritillary, *Speyeria idalia,* and wild indigo duskywing, *Erynnis baptisiae*) in public garden habitats suggests that these areas have some potential to provide habitat for relatively rare species, however these species accounted for only three of our observations. Thus, although urban areas can offer resources that support some habitat specialists and species of concern, it is also true that habitat fragmentation and low species mobility may restrict their movement into urban habitats in general, and the scale at which these habitats can meet conservation needs may be limited (Warren et al. 2001; Concepción et al. 2015).

Comparison of habitat types

We observed the highest numbers of both individual butterflies and different species in public gardens, but differences between habitat types were not significant. This contradicts previous studies in which researchers observed fewer butterflies and lower species diversity in areas with increased levels of human disturbance (Di Mauro et al. 2007; Öckinger et al. 2009). However, other studies have shown that, rather than proximity to urban development, the characteristics of the habitat itself, including vegetation structure, as well as habitat quality and diversity, have greater influence on butterfly species richness (Collinge et al. 2003; Botham et al. 2015) and abundance (Collinge et al. 2003). This is not to say that butterfly species richness or abundance at any given site reflects the ability of the site to actually sustain butterfly populations – there may be instances when small habitat areas embedded in an urban matrix are ecological traps (e.g., Battin 2004;

Table 5 Occupancy models, mean Akaike information criterion scores (μAIC), ΔAIC, and Akaike weights (w_i) generated for butterfly sightings based on standardized data for habitat types and survey methods. *p* indicates detection and Ψ indicates occupancy. "~Survey" refers to survey method, "~Environ" refers to habitat type, and "~Year" refers to the year in which the survey was completed. Models listed are ≤3.0 ΔAIC from the best model for all families combined and for each family. The model we chose for all families and for each family is indicated in bold typeface

Model	μAIC	ΔAIC	w_i
All Families			
p (~Environ)Ψ(~Year)	112.30	0.00	0.26
p (~Environ)Ψ(~1)	113.30	1.00	0.16
p (~Survey + Environ)Ψ(~Year)	113.82	1.51	0.12
***p* (~Survey + Environ)Ψ(~1)**	**114.31**	**2.01**	**0.09**
p (~1)Ψ(~Year)	114.35	2.04	0.09
Hesperiidae			
p (~1)Ψ(~Year)	64.85	0.00	0.47
p (~Environ)Ψ(~Year)	65.94	1.09	0.27
p (~Survey)Ψ(~Year)	67.85	3.00	0.11
Lyceanidae			
***p* (~Survey + Environ)Ψ(~1)**	**108.18**	**0.00**	**0.21**
p (~1)Ψ(~Environ)	108.50	0.32	0.18
p (~Environ)Ψ(~1)	108.89	0.71	0.15
p (~Survey)Ψ(~Environ)	109.70	1.52	0.10
p (~Environ)Ψ(~Environ)	110.39	2.21	0.07
p (~Survey + Environ)Ψ(~Year)	110.58	2.40	0.06
p (~Environ)Ψ(~Year)	110.64	2.46	0.06
p (~Survey + Environ)Ψ(~Environ)	110.78	2.60	0.06
Nymphalidae			
p (~Environ)Ψ(~1)	124.00	0.00	0.15
p (~Environ)Ψ(~Year)	124.19	0.19	0.14
p (~1)Ψ(~Year)	124.29	0.29	0.13
p (~1)Ψ(~1)	124.39	0.40	0.12
p (~1)Ψ(~Environ)	124.42	0.42	0.12
***p* (~Survey + Environ)Ψ(~1)**	**125.62**	**1.63**	**0.07**
p (~Survey)Ψ(~1)	125.80	1.80	0.06
p (~Survey)Ψ(~Year)	125.89	1.90	0.06
p (~Survey + Environ)Ψ(~Year)	126.14	2.14	0.05
p (~Survey)Ψ(~Environ)	126.23	2.24	0.05
p (~Environ)Ψ(~Environ)	126.41	2.41	0.04
Papilionidae			
***p* (~Survey + Environ)Ψ(~1)**	**86.32**	**0.00**	**0.16**
p (~Survey)Ψ(~1)	86.52	0.20	0.14
p (~Survey)Ψ(~Environ)	87.15	0.83	0.10
p (~Survey)Ψ(~Year)	87.34	1.03	0.09
p (~Environ)Ψ(~1)	87.42	1.10	0.09
p (~Survey + Environ)Ψ(~Year)	87.44	1.12	0.09
p (~1)Ψ(~1)	87.92	1.60	0.07
p (~Environ)Ψ(~Year)	87.96	1.64	0.07
p (~1)Ψ(~Year)	88.25	1.93	0.06
p (~1)Ψ(~Environ)	88.34	2.03	0.06
p (~Survey + Environ)Ψ(~Environ)	89.16	2.85	0.04
p (~Environ)Ψ(~Environ)	89.26	2.94	0.04
Pieridae			
***p* (~Survey + Environ)Ψ(~1)**	**184.03**	**0.00**	**0.34**
p (~Environ)Ψ(~1)	184.82	0.79	0.23
p (~Survey + Environ)Ψ(~Year)	185.83	1.80	0.14
p (~Environ)Ψ(~Year)	186.07	2.04	0.12
p (~Survey + Environ)Ψ(~Environ)	186.78	2.75	0.09

Robertson and Hutto 2006) or function simply as waypoints along migratory pathways.

Comparison of survey methods

Both our analyses of variance and detection estimates indicated that survey method strongly influenced the number of butterflies we observed. We observed relatively few butterflies by using Pollard transects. In extreme cases, as with Papilionidae species, it was estimated that 93% of potential sightings went undetected in public gardens and 97% were undetected in prairie areas when using Pollard transects. The fixed location of these transects may undercount localized, sedentary or elusive species (Royer et al. 1998; Shuey and

Table 6 Detection estimates and 95% confidence intervals calculated for each family by habitat (public gardens and prairie areas) and survey method (Pollard transects, purposive, and random point counts)

	Public gardens		
Survey method and butterfly family	Detection estimate	Lower confidence interval	Upper confidence interval
Pollard transects			
Lycaenidae	0.41	0.28	0.56
Nymphalidae	0.59	0.45	0.72
Papilionidae	0.07	0.02	0.19
Pieridae	0.67	0.52	0.79
Purposive point counts			
Lycaenidae	0.55	0.41	0.69
Nymphalidae	0.76	0.63	0.86
Papilionidae	0.31	0.19	0.47
Pieridae	0.88	0.77	0.94
Random point counts			
Lycaenidae	0.38	0.21	0.60
Nymphalidae	0.50	0.36	0.64
Papilionidae	0.11	0.04	0.24
Pieridae	0.63	0.48	0.76
	Prairie areas		
Survey method and butterfly family	Detection estimate	Lower confidence interval	Upper confidence interval
Pollard transects			
Lycaenidae	0.20	0.11	0.32
Nymphalidae	0.47	0.34	0.61
Papilionidae	0.03	0.01	0.09
Pieridae	0.65	0.48	0.79
Purposive point counts			
Lycaenidae	0.30	0.19	0.45
Nymphalidae	0.66	0.52	0.78
Papilionidae	0.14	0.07	0.28
Pieridae	0.88	0.76	0.94
Random point counts			
Lycaenidae	0.18	0.08	0.36
Nymphalidae	0.38	0.26	0.52
Papilionidae	0.04	0.01	0.12
Pieridae	0.61	0.47	0.74

Table 7 Sum of Akaike weights for determining variable importance to estimate occupancy and detection for all species combined and by family

	Occupancy		Detection	
Taxa	Year	Habitat type	Habitat type	Survey method
All species	0.51	0.16	0.71	0.33
Hesperiidae	0.90	0.03	0.36	0.18
Lycaenidae	0.16	0.41	0.62	0.48
Nymphalidae	0.37	0.23	0.46	0.30
Papilionidae	0.31	0.23	0.44	0.62
Pieridae	0.26	0.16	1.00	0.57

Szymanski 2012). Because of this, Pollard transects are often modified according to habitat characteristics or research purpose, sometimes to the extent that they more closely resemble meandering or visual-encounter surveys (e.g., Collinge et al. 2003; Vogel et al. 2010). Although Pollard transects can be placed specifically to pass through optimal habitats, especially in public gardens, there are also likely to be less suitable areas (such as areas of mown lawn) along the distance covered by transects, which may decrease the frequency of butterfly sightings. In prairie habitats, where the amount and location of floral resources change over time, the fixed location of Pollard transects may also decrease the overall number of sightings across a season compared to methods that allow surveyors to meander within a habitat. At the same time, Pollard transects may be better for long-term monitoring or to detect trends over time at a particular location (e.g., Pleasants et al. 2017).

Our purposive point-count surveys accounted for two-thirds of all sightings, which is not surprising since the points where we focused these observations were in areas providing abundant resources, primarily tied to floral cover. Purposive point counts in gardens allowed survey effort to be concentrated in areas where butterflies were more likely to be present, increasing the probability of sightings. Further, purposive point surveys conducted in prairie areas can facilitate observations that follow natural changes in the location and density of floral resources over time. Thus, survey effort can focus more efficiently on areas where sightings are more likely. Especially for collection of species-specific data, surveyors may choose to conduct purposive point surveys to facilitate examination of particular habitat types (e.g., Royer et al. 1998; Henry et al. 2015; Kral et al. 2018).

Our random point-count results were similar to those from Pollard transects. Random point counts can be used in butterfly surveying to allow for unbiased estimation of butterfly density within a habitat, especially to develop comparisons over time (Henry et al. 2015). Although this makes random point counts desirable for surveying purposes, they are less useful for detecting species with specific habitat needs (e.g., thick brush, or species-specific host plants) if none of the random points is located within the necessary habitat (Henry et al. 2015).

Occupancy models

Model selection The occupancy model we selected did not include survey year or habitat type. We did not expect survey year to be a significant factor, because our surveys covered a broad range of lepidopteran species with differing environmental requirements and were conducted during the same time interval each year under a narrow range of specified weather conditions. Further, the likelihood of habitat type affecting butterfly family occupancy at these sites was low, since nearly 95% of the butterflies we detected were habitat generalists. For detection, however, habitat type was important, and detection estimates were higher in gardens. This may be related to relative ease of observing butterflies when they are present because the floral resources that attract them are more clustered and the areas between them allow better visual access in intensively managed landscapes. In addition, in some cases intentional garden designs and use of plant species in those designs provide important resources to attract butterflies. In contrast, in prairie areas where floral resources were more evenly distributed, differences in our ability to detect butterflies, while still significant, were not as pronounced.

Detection estimates and importance values Detection estimates were relatively high for purposive point counts. For example, for the Lycaenidae, detection estimates using purposive point surveys were 34% greater in gardens and 53% greater in prairie areas. And, although detection estimates were lower overall for the Papilionidae, they were 343% and 367% greater for purposive point counts than for Pollard transects in gardens and prairie areas, respectively. For other families, we also observed somewhat greater detection estimates for purposive point counts compared to Pollard transects, but the relative differences were smaller.

Survey efficiency can vary depending on the array of species occupying a site (Kéry and Plattner 2007), and our ability to detect butterflies may have been affected by species-specific behaviors. Other researchers have reported that Pollard transects may not be effective for detecting butterflies which have secretive behaviors, such as generally low flight, habits of resting in covered areas, infrequent nectaring, and/or being relatively sedentary (e.g., Shuey and Szymanski 2012). Compared to Pollard transects, purposive point counts can more easily focus on specific habitat requirements (e.g., specific host plants or structural characteristics). The higher detection estimates we observed with purposive point counts may also translate to less survey effort required to determine species occupancy within a site. For example, Kéry and Plattner (2007) suggested that it may take up to 20 Pollard transects to approach detection rates close to one. However, in the urban areas we explored, our data suggest that purposive point counts may make it possible to reduce the survey time and/or survey area needed to detect a species. Species-specific characteristics may also affect detectability. For example, detection estimates were significantly lower for the Papilionidae than for three other families with respect to both habitat type and survey method. It is possible that detection estimates are lower for the Papilionidae because they are stronger flyers and move across greater distances that exceed the "envelope" of space-constrained sampling methods.

Importance values were relatively high for detection by survey method for species in two families, the Papilionidae and Pieridae, and were moderately high for the Lycaenidae. Survey method was less important for detection of species in the Hesperiidae. This could be because observers' movements associated with Pollard transects may flush males of the Hesperiidae, thus butterfly behavior itself increases the relative effectiveness of that method compared to the other two.

Summary and conclusions

Our findings confirm that urban areas, such as public gardens and restored prairies, provide important habitat for butterflies, and that a variety of butterfly species, including a limited number of habitat specialists, are present in these areas.

However, we cannot determine if the presence of these species in these settings sustains their populations (i.e., through successful reproduction). Purposefully created habitat in urban settings, particularly for urban areas in landscape matrices that otherwise have limited resources for butterflies (e.g., intensively managed agricultural landscapes), can likely support a number of butterflies and species richness similar to that of larger, more rural habitat areas within the same eco-region. It is important to note that our study sites were all relatively large (ranging from 1.1 ha to 2.5 ha) in comparison to habitats that may be created by individual homeowner participants in outreach programs, such as those offered by local and national conservation organizations. Determining the effectiveness of those broadly dispersed but very small-scale features, such as individual home gardens, could likely be accomplished by using purposive point-count surveys and provide additional information useful for municipal-scale conservation efforts.

We did not detect differences in the number of butterflies in public gardens compared to restored/reconstructed prairie areas. Some factors that we did not quantify in our analyses, including vegetation structure and diversity, amount of organic matter, or other edaphic characteristics of specific locations, could play a role in habitat selection by butterflies. Based on our findings, even though habitat specialists were present in both prairie and garden habitats, they accounted for a small percentage of our observations. Special consideration could be given to developing high-quality areas for habitat specialists within urban settings, such as mass plantings of specific host plants or landscape configurations that provide for other habitat structure needs.

Although Pollard transects have long been a standard method for butterfly surveys, in this study, they generated relatively few butterfly observations. All of our analyses indicate that purposive point surveys were more effective in both urban habitat types than were the other survey methods we tested. We consistently observed greater numbers of butterflies and butterfly species by using purposive point-count surveys and would recommend standardizing this method for butterfly surveys in relatively small, urban habitat areas. Further, based on areas where we observed large numbers of butterflies, we suggest that both garden and prairie designs could be enhanced by including more, denser and/or larger clusters of floral resources that would attract and benefit butterfly populations.

Acknowledgements Support for this study was provided by Reiman Gardens, the Department of Natural Resource Ecology and Management at Iowa State University, the Iowa Department of Natural Resources, and McIntire-Stennis funds. We thank personnel in the Park and Recreation Departments of the Cities of Ames and Des Moines, and at the Greater Des Moines Botanical Gardens, the Iowa Association of Municipal Utilities, the Nature Conservancy, and Reiman Gardens for allowing access to sites to conduct butterfly surveys. We also thank Julia Schwager, Sarah Rueger, Camille Karnatz, and Stephen Potter for field and laboratory assistance. We appreciate statistical advice from Tyler Harms and additional advice and information provided by Nathan Brockman, Aaron Steil, Kelly Norris, Jim Durbin and Dave Hraha. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the United States Government.

References

Akaike H (1974) A new look at the statistical model identification. IEEE Trans Auto Control 19:716–723

Alcock J (1994) Alternative mate-locating tactics in *Chlosyne californica* (Lepidoptera, Nymphalidae). Ethology 97:103–118

Battin J (2004) When good animals love bad habitats: ecological traps and the conservation of animal populations. Conserv Biol 18:1482–1491

Bitzer RJ, Shaw KC (1979) Territorial behavior of the red admiral, *Vanessa atalanta* (L.) (Lepidoptera: Nymphalidae). J Res Lepid 18:36–49

Blair RB (1999) Birds and butterflies along an urban gradient: surrogate taxa for assessing biodiversity? Ecol Appl 9:164–170

Bolund P, Hunhammar S (1999) Ecosystem services in urban areas. Ecol Econ 29:293–301

Botham MS, Fernandez-Ploquin EC, Brereton T, Harrower CA, Roy DB, Heard MS (2015) Lepidoptera communities across an agricultural gradient: how important are habitat area and habitat diversity in supporting high diversity? J Insect Conserv 19:403–420

Brown JA, Boyce MS (1998) Line transect sampling of Karner blue butterflies (*Lycaeides melissa samuelis*). Environ Ecol Stat 5:81–91

Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information-theoretic approach, 2nd edn. Springer-Verlag, New York

Cameron SA, Lozier JD, Strange JP, Koch JB, Cordes N, Solter LF, Griswold TL (2011) Patterns of widespread decline in north American bumblebees. Proc Natl Acad Sci USA 108:662–667

Carneiro E, Mielke OHH, Casagrande MM, Fiedler K (2014) Skipper richness (Hesperiidae) along elevational gradients in Brazilian Atlantic forest. Neotrop Ent 43:27–38

Clark PJ, Reed JM, Chew FS (2007) Effects of urbanization on butterfly species richness, guild structure, and rarity. Urban Ecosyst 10:321–337

Collier N, Mackay DA, Benkendorff K, Austin AD, Carhew SM (2006) Butterfly communities in south Australian urban reserves: estimating abundance and diversity using the Pollard walk. Austral Ecol 31: 282–290

Collinge SK, Prudic KL, Oltver AC (2003) Effects of local habitat characteristics and landscape context on grassland butterfly diversity. Conserv Biol 17:178–187

Concepción ED, Moretti M, Altermatt F, Nobis MP, Obrist MK (2015) Impacts of urbanisation on biodiversity: the role of species mobility, degree of specialisation and spatial scale. Oikos 124:1571–1582

Concepción ED, Obrist MK, Moretti M, Altermatt F, Baur B, Nobis MP (2016) Impacts of urban sprawl on species richness of plants, butterflies, gastropods and birds: not only built-up area matters. Urban Ecosyst 19:225–242

Debinski DM, Kelly L (1998) Decline of Iowa populations of the regal fritillary (*Speyeria idalia*). J Iowa Acad Sci 105:16–22

Delaney JT, Jokela K, Debinski DM (2015) Seasonal succession of pollinator floral resources in four grassland types in the tallgrass prairie ecoregion. Ecosphere 6(11):1–14

Dennis EB, Morgan BJT, Roy DB, Brereton TM (2017) Urban indicators for UK butterflies. Ecol Indic 76:184–193

Di Mauro D, Dietz T, Rockwood L (2007) Determining the effect of urbanization on generalist butterfly species diversity in butterfly gardens. Urban Ecosyst 10:427–439

Dirzo R, Young HS, Galetti M, Ceballos G, Isaac NJ, Collen B (2014) Defaunation in the anthropocene. Science 345:401–406

ESRI (2015) ArcGIS desktop: release 10.1 Environmental Systems Research Institute, Redlands, CA

ESRI (2016) ArcGIS desktop: release 10.2 Environmental Systems Research Institute, Redlands, CA

Gallant AG, Sadinski W, Roth MF, Rewa CA (2011) Changes in historical Iowa land cover as context for assessing the environmental benefits of current and future conservation efforts on agricultural land. J Soil Water Cons 66(3):67–77

Giuliano W, Accamando A, McAdams E (2004) Lepidoptera-habitat relationships in urban parks. Urban Ecosyst 7:361–370

Hardy PB, Dennis RL (1999) The impact of urban development on butterflies within a city region. Biodivers Conserv 8:1261–1279

Hartzler RG (2010) Reduction in common milkweed (*Asclepias syriaca*) occurrence in Iowa cropland from 1999 to 2009. Crop Prot 29: 1542–1544

Hartzler RG, Buhler DD (2000) Occurrence of common milkweed (*Asclepias syriaca*) in cropland and adjacent areas. Crop Prot 19: 363–366

Henry EH, Haddad NM, Wilson J, Hughes P, Gardner B (2015) Point-count methods to monitor butterfly populations when traditional methods fail: a case study with Miami blue butterfly. J Insect Conserv 19:519–529

Houseal G, Smith D (2000) Source-identified seed: the Iowa roadside experience. Ecol Rest 18:173–183

Iowa Department of Natural Resources (IDNR) (2006) Butterfly monitoring protocol. In: Iowa multiple species inventory and monitoring program technical manual, pp 65–70

Iowa Department of Natural Resources (IDNR) (2007) Securing a future for fish and wildlife: The Iowa wildlife action plan. Available at IDNR, www.iowadnr.gov/Environment/WildlifeStewardship/IowaWildlifeActionPlan (Accessed 28 October 2014)

Iowa State University (ISU) Extension (2016) Crops and land use: statewide data. Available at ISU Extension, https://www.extension.iastate.edu/soils/crop-and-land-use-statewide-data (Accessed 11 July 2017)

Isaac NJB, Cruickshanks KL, Weddle AM, Marcus Rowcliffe J, Brereton TM, Dennis RLH, Shuker DM, Thomas CD (2011) Distance sampling and the challenge of monitoring butterfly populations. Methods Ecol Evol 2:585–594

Kadlec T, Benes J, Jarosik V, Konvicka M (2008) Revisiting urban refuges: changes of butterfly and burnet fauna in Prague reserves over three decades. Landsc Urban Plann 85:1–11

Kéry M, Plattner M (2007) Species richness estimation and determinants of species detectability in butterfly monitoring programmes. Ecol Entomol 32:53–61

Kral K, Harmon J, Limb R, Hovick T (2018) Improving our science: the evolution of butterfly sampling and surveying methods over time. J Insect Conserv 22:1–14

Laake, JL (2013) RMark: An R interface for analysis of capture-recapture data with MARK. AFSC Proc Rep 2013–01, 25 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Seattle, WA

MacKenzie DI, Nichols JD, Lachman GB, Droege S, Royle JA, Langtimm CA (2002) Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255

Maes D, Van Dyck H (2001) Butterfly diversity loss in Flanders (North Belgium): Europe's worst case scenario? Biol Conserv 99:263–276

Matteson KC, Langellotto G (2010) Determinants of inner city butterfly and bee species richness. Urban Ecosyst 13:333–347

Matteson KC, Grace JB, Minor ES (2013) Direct and indirect effects of land use on floral resources and flower-visiting insects across an urban landscape. Oikos 122:682–694

McKinney M (2008) Effects of urbanization on species richness: a review of plants and animals. Urban Ecosyst 11:1573–1642

Menninger HL, Palmer MA (2006) Restoring ecological communities: from theory to practice. In: Falk DA, Palmer MA, Zedler JB (eds) Foundations of restoration ecology. Island Press, Washington, D.C., pp 88–112

Moranz RA, Debinski DM, McGranahan DA, Engle DM, Miller JR (2012) Untangling the effects of fire, grazing, and land-use legacies on grassland butterfly communities. Biodivers Conserv 21:2719–2746

Myers MC, Hoksch BJ, Mason JT (2012) Butterfly response to floral resources during early establishment at a heterogeneous prairie biomass production site in Iowa, USA. J Insect Conserv 16:457–472

National Oceanic and Atmospheric Administration (NOAA) (2017) National Centers for Environmental Information – U.S. Agricultural Belts. Accessed at: https://www.ncdc.noaa.gov/monitoring-references/maps/us-ag-belts.php, 11/20/2017

Öckinger E, Dannestam Å, Smith HG (2009) The importance of fragmentation and habitat quality of urban grasslands for butterfly diversity. Landsc Urban Plann 93:31–37

Panzer R, Gnaedinger K, Derkovitz G (2010) The prevalence and status of conservative prairie and sand savanna insects in the Chicago wilderness region. Nat Areas J 1:73–81

Pellet J (2008) Seasonal variation in detectability of butterflies surveyed with Pollard walks. J Insect Conserv 12:155–162

Pleasants JM, Zalucki MP, Oberhauser KS, Brower LP, Taylor OR, Thogmartin WE (2017) Interpreting surveys to estimate the size of the monarch butterfly population: pitfalls and prospects. PLoS ONE 12(7): e0181245Pollard E (1977) a method for assessing changes in the abundance of butterflies. Biol Conserv 12:115–134

Pollard E, Yates T (1994) Monitoring butterflies for ecology and conservation: the British monitoring scheme. Chapman & Hall, London

Posa MRC, Sodhi NS (2006) Effects of anthropogenic land use on forest birds and butterflies in Subic Bay, Philippines. Biol Conserv 129: 256–270

R Core Team (2013) R (Version 3.0.2): A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria

Reeder KF, Debinski DM, Danielson BJ (2005) Factors affecting butterfly use of filter strips in Midwestern USA. Agric Ecosyst Environ 109:40–47

Ries LD, Debinski DM, Wieland M (2001) Conservation value of roadside prairie restoration to butterfly communities. Conserv Biol 15: 401–411

Robertson BA, Hutto RL (2006) A framework for understanding ecological traps and an evaluation of existing evidence. Ecology 87:1075–1085

Royer RA, Austin JE, Newton WE (1998) Checklist and "Pollard walk" butterfly survey methods on public lands. Am Midl Nat 140:358–371

SAS (2017) JMP 12.0.1. SAS Institute, Inc., Cary, NC

Schlicht DW, Downey JC, Nekola JC (2007) The butterflies of Iowa. University of Iowa Press, Iowa City

Scott JA (1973) Convergence of population biology and adult behaviour in two sympatric butterflies, *Neominois ridingsii* (Papilionoidea: Nymphalidae) and *Amblyscirtes simius* (Hesperioidea: Hesperiidae). J Anim Ecol 42:663–672

Shepherd S, Debinski DM (2005) Evaluation of isolated and integrated prairie reconstructions as habitat for prairie butterflies. Biol Conserv 126:51–61

Shuey J, Szymanski J (2012) Modified Pollard transects do not predict estimated daily population size for the secretive butterfly, *Neonympha mitchellii mitchellii* French. J Lepid Soc 66:221–224

Stefanescu C, Herrando S, Páramo F (2004) Butterfly species richness in the north-West Mediterranean Basin: the role of natural and human-induced factors. J Biogeogr 31:905–915

Stigler SM (1982) Poisson on the Poisson distribution. Stat Prob Letters 1:33–35

Swengel SR, Schlicht D, Olsen F, Swengel AB (2011) Declines of prairie butterflies in the midwestern USA. J Insect Conserv 15:327–339

Van Dyck H, Van Strien AJ, Maes D, Van Swaay CAM (2009) Declines in common, widespread butterflies in a landscape under intense human use. Conserv Biol 23:957–965

Van Swaay CAM, Brereton T, Kirkland P, Warren MS (2012) Manual for butterfly monitoring. Report VS2012.010. De Vlinderstichting/ Dutch butterfly conservation, butterfly conservation UK and butterfly conservation Europe, Wageningen, the Netherlands

Vogel JA, Koford RR, Debinski DM (2010) Direct and indirect responses of tallgrass prairie butterflies to prescribed burning. J Insect Conserv 14:663–677

Wagenmakers EJ, Farrell S (2004) AIC model selection using Akaike weights. Psychon Bull Rev 11:192–196

Warren MS, Hill JK, Thomas JA, Asher J, Fox R, Huntley B, Thomas CD (2001) Rapid responses of British butterflies to opposing forces of climate and habitat change. Nature 414:65–69

Yahner RH (2001) Butterfly communities in residential landscapes of Central Pennsylvania. Northeast Nat 8:113–118