

Evaluating butterflies as surrogates for birds and plants in semi-natural grassland buffers

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Abstract Semi-natural grasslands can support diverse faunal and floral communities, including grassland birds, beneficial insects, and native wildflowers. Monitoring biodiversity of this type of ecosystem is important to assess abundance and richness of grassland-associated species, evaluate success of establishing grasslands, and to assess overall ecosystem health. We tested butterflies as surrogates for birds and plants to assess establishment success of semi-natural grassland buffers in north-central Mississippi using Spearman rank correlation (Spearman's ρ). Disturbance and grassland butterfly guilds were generally not suitable surrogates for grassland bird metrics, non-grassland bird metrics, or nest density metrics. Butterflies did have consistent positive correlations with plant species richness and forb metrics, as well as consistent negative correlations with grass metrics, but these correlations were generally smaller than what is considered suitable to serve as surrogates. In general, butterflies were not suitable surrogates for birds or plants in semi-natural grassland buffers.

Keywords Birds · Butterflies · Grass buffers · Plants · Species richness · Surrogate

Introduction

Semi-natural grasslands like those provided by agricultural conservation programs [e.g., United States Department of Agriculture (USDA) Conservation Reserve Program and the European Union's Agri-Environment Schemes] can support components of biodiversity (e.g., Weibull et al. 2003) including grassland birds (e.g., Conover et al. 2011), beneficial insects (e.g., Ockinger and Smith 2007), and butterflies (e.g., Field et al. 2005). In North America, semi-natural grasslands could potentially mitigate grassland biodiversity losses resulting from elimination of most native Tallgrass Prairie in agricultural regions (e.g., Samson and Knopf 1994; Peterjohn 2003; Flynn et al. 2009). For example, semi-natural grasslands could help alleviate negative population trends in both grassland-nesting birds (Peterjohn et al. 1994) and prairie-associated butterflies (Opler and Krizek 1984; Johnson 1986; Swengel 1993). Likewise, native prairie plant communities are often restricted to small, isolated remnants and restoration projects (e.g., Packard and Mutel 1997). Evaluating the successful establishment and biodiversity function of recently established grassland requires monitoring of multiple taxa which can be expensive and labor-intensive. Using surrogate taxa (also referred to as indicators in the literature) may be a useful alternative. Surrogacy is a relation between a surrogate or indicator variable and a target variable where the surrogate represents (i.e., is correlated strongly with) the target variable(s) (Sarkar and Margules 2002; Lovell et al. 2007).

Butterflies (Lepidoptera) have been proposed as potential surrogates for birds and plants (Swengel and Swengel 1997, 1999; Blair 1999; Pearman and Weber 2007; Fleishman and

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Murphy 2009) in part because they are well-studied and charismatic (e.g., Kurtz et al. 2001; Nelson 2007) and often have coevolved strong associations with plant species (or groups of plant species) because butterflies require a variety of plant species (e.g., host plants, nectar plants) to complete their life-cycle (e.g., Kremen 1992; Ries et al. 2001; Reeder et al. 2005; Aviron et al. 2010). In grasslands, positive correlations may exist between prairie-specialist butterflies and grassland songbird abundance (Swengel and Swengel 1997, 1998, 1999). However, correlations between taxonomic groups can be highly variable among different spatial scales or habitat types (Weaver 1994; Prendergast and Eversham 1997; Swengel and Swengel 1998; Blair 1999; Ricketts et al. 1999), and the utility of butterflies as indicators varies because of these and other factors (see Fleishman and Murphy 2009 and references therein). Thus translating results from natural grassland remnants (e.g., Swengel and Swengel 1999) or previously established, semi-natural grasslands (e.g., pastures, sensu Vessby et al. 2002) to semi-natural grassland established on what was recently cropland would be unwise. If butterflies have sufficiently strong associations with birds or plants in recently-established, semi-natural grasslands that are part of agricultural conservation programs, they would make useful indicators of establishment success, but this research has not been conducted.

To fill this knowledge gap, we evaluated whether butterflies could be suitable surrogates of birds and plants in semi-natural grassland buffers established in 2005 as part of the USDA Conservation Reserve Program. We predicted that grassland butterflies and grassland birds would be correlated positively with each other because both taxa require early-successional grassland plant communities for at least part of their life history and should benefit from newly established grassland habitat. We predicted that generalist butterflies and birds would not be as strongly correlated with each other because while they are often common in grasslands, their habitat requirements are broader and not exclusive to grasslands. Although recent work with butterflies as surrogates has focused on correlations between richness and abundance metrics (e.g., Swengel and Swengel 1999; Pearman and Weber 2007), we went one step further and tested if butterfly metrics were correlated with bird nest density. We also evaluated whether butterflies could be surrogates for plant communities. We predicted that abundance and species richness of both grassland butterflies (and to a lesser degree, generalist butterflies) would be positively correlated with higher plant species richness and more forbs.

Methods

Study site and experimental design

We worked at B. Bryan Farms, a privately-owned farm with row-crop and grazing operations in Clay County,

Mississippi. Located in the historic Blackland Prairie physiographic region of northeast Mississippi, the region has a pre-European settlement history of frequent fire and grazing ungulate herds and a post-European settlement history of agricultural development and fire suppression (Peacock and Schauwecker 2003). During spring 2005, 79 crop hectares were retired under Conservation Reserve Program (CRP) Practice CP33—Habitat Buffers for Upland Birds which are 18.2–36.5 m wide linear strips of native herbaceous vegetation around agricultural field margins (USDA 2004). CP33 buffers were planted with native warm-season grasses and forbs associated with the regional Blackland Prairie ecosystem (Hale et al. 2011; Table S1 in Supplemental Material) surrounding fields planted in soybean (*Glycine max*), corn (*Zea mays*), or Bermudagrass hay (*Cynodon dactylon*). Periodic disturbance of CP33 is required by contract (USDA 2004) to inhibit woody plants and maintain buffers in an early-successional grassland plant community (Benson et al. 2007). During 2 years (2008 and 2009) of this study, 1/4 of the buffers were either prescribed burned or disked each year as part of related management experiments (Hale et al. 2011; Adams et al. 2013; Dollar et al. 2013). To evaluate butterflies as surrogates, we only used undisturbed buffers because birds, butterflies, and plants may respond independently to disturbance, possibly confounding true surrogate relationships with common responses to disking and burning. Thus, the number of buffers included in surrogate analyses decreased each year (2007: $n = 43$ for butterflies vs. birds, $n = 24$ butterflies vs. plants; 2008: $n = 33$ for butterflies vs. birds, $n = 16$ butterflies vs. plants; 2009: $n = 24$ for butterflies vs. birds, $n = 9$ butterflies vs. plants).

Butterfly counts

To sample butterflies, 3 50-m transects (Pollard and Yates 1993) were placed in the center along the long axis of each buffer (Figure S1) to prevent double counting of individuals (Swengel and Swengel 1999). Along each 50-m transect, we counted butterflies (Papilionidae) and skippers (Hesperiidae) 6 times each summer (June–August 2007–2009) from 8 a.m. to 1 p.m. CST (Dollar et al. 2013) in favorable weather (Ries et al. 2001). Transects were walked at a constant rate of 10 m per minute, and all butterflies within 5 m of either transect side were counted and identified to species level (Ries et al. 2001). Butterflies were identified on the wing if possible, otherwise they were netted and released. Due to difficulty of field identification, *Colias eurytheme* and *C. philodice* were identified to genus and pooled during the analyses (sensu Ries et al. 2001; Reeder et al. 2005). Both species are common in Mississippi and share similar host plants.

Bird counts and nest density

To estimate abundance and species richness of breeding birds, we used 200-m transects established for a related management experiment (Adams et al. 2013) which overlapped the 3 butterfly transects in each buffer (butterflies and birds were not sampled on the same days). Each transect was traversed at a rate of 10 m per minute and bird species observed in buffers were recorded. Counts were conducted 6 times during each breeding season (twice monthly) from 5:30 a.m. to 10:00 a.m. CST on mornings with no precipitation and wind speeds <15 mph (Smith et al. 2005). The same observer conducted all bird counts. Because distance sampling analyses (Buckland et al. 2001; Thomas et al. 2010) selected uniform detection functions with detectability at or near 1.00 (Adams 2011), we assumed 100 % detection and used unadjusted bird counts. To locate nests, technicians systematically searched buffers every 2 weeks for a total of 6 times during the bird breeding season (May–early August; Adams et al. 2013).

Plant sampling

We characterized buffer habitat structure in late-July through early-August in 2007–2009 using 0.25-m² sampling plots (Ries et al. 2001) at 6 locations positioned systematically along each 50-m transect (Figure S1). We recorded percentage cover of grasses, native warm-season grass, forbs, and litter and number of flowering stems. In the center of each quadrat, a 2-m long metal rod was placed vertically through vegetation to record grass height and grass density (Riffell et al. 2003).

We used a more intensive sampling method (i.e., standard 1-m² quadrats; Roberts-Pichette and Gillespie 1999) for sampling the buffer plant community to species level (Dollar 2011). We collected measurements from 30 quadrats per buffer, a sufficient number of samples to capture species richness as determined by a species accumulation curve (Roberts-Pichette and Gillespie 1999; Dollar 2011). Percentage cover of each plant species, litter, and bare ground and stem counts of all forbs, vines, and shrubs (taller than 1-cm) were recorded. We positioned sampling quadrats 5- to 10-m perpendicular to the transect line to avoid impacts of researcher disturbance from the butterfly and bird sampling activity (Figure S1). These methods were used once in 2007 (August), 3 times in 2008 (May, July, and August), and 3 times in 2009 (May, July, and August).

Statistical analyses

Butterfly metrics

Butterflies were classified into one of three guilds based on previous studies (Swengel and Swengel 1999; Reeder et al.

2005; Davros et al. 2006; Vogel et al. 2007) and known plant associations (Scott 1986; Opler and Malikul 1992; Glassberg 1999; Bouseman et al. 2006; Table S2). Generalist guild species are typically associated with disturbed habitats and have a broad range of host and nectar plants, relatively high dispersal rates, and several broods per year. Grassland guild species, in contrast, have more specific host and nectar plants, lower dispersal rates, and one or two broods per year. Species which prefer forested habitats were sometimes detected on the buffers. These species were included in the butterfly abundance and species richness estimates, but individual species were not included due to their habitat preference and low number of detections.

We calculated abundance variables for those butterfly species which were detected on ≥ 70 % of buffers throughout the study period. These species were: common buckeye (*Junonia coenia*), cloudless sulfur (*Phoebis sennae*), pearl crescent (*Phyciodes tharos*), orange sulfur/clouded sulfur (*Colias philodice/C. eurytheme*), little yellow (*Pyrisitia lisa*), sleepy orange (*Abaeis nicippe*), and fiery skipper (*Hylephila phyleus*). Butterfly abundance of each guild and abundance of the most common species were summed over the 3 transects per buffer and averaged over the six visits each summer. We estimated species richness of each guild as cumulative richness over the three transects and six visits for each buffer.

Bird metrics

Bird species were grouped into one of two guilds based on previous studies and known habitat associations (Vickery et al. 1999; Adams 2011; Table S3). Species were grouped into the grassland guild if they were obligate or facultative grassland birds (Vickery et al. 1999). All other species were grouped into the non-grassland guild. Bird abundance, abundance for each guild, and abundance for the two most common species—red-winged blackbird (*Agelaius phoeniceus*) and dickcissel (*Spiza americana*)—were averaged over the six sampling periods each year. We estimated bird species richness, grassland guild species richness, and non-grassland guild species richness as the cumulative richness over six visits for each buffer. We also calculated abundance of the two most common species detected in the buffers, which comprised 61 % of total detections and 71 % of all nests found. We calculated nest density (#/ha) for all birds, red-winged blackbird, and dickcissel using ArcGIS (Environmental Systems Research Institute, Inc., Redlands, CA) to estimate area of each buffer and GPS locations of nests.

Plant metrics

Habitat variables were averaged over the six sampling locations per transect and the three transects per buffer.

Plant composition variables were averaged over the 30 sampling locations per transect. Plant species richness was calculated by summing richness over the 30 samples per buffer. Sampling periods (i.e., early, mid, and late summer) and year were analyzed separately. Plant species were placed into functional groups (NRCS 2010; Table S1). Individual plant species were chosen because they were the major components of the CP33 planting mix and hence, important for evaluating establishment.

Correlation analyses

We used Spearman rank correlation (Spearman's ρ) to measure how butterfly metrics correlated with bird metrics and plant metrics instead of Pearson correlation because many variables did not meet assumptions about normality, homoscedasticity, and linearity (Swengel and Swengel 1999; Lovell et al. 2007; Pearman and Weber 2007). ρ indicates strength of the observed relationship with 0 denoting no relation and ± 1 denoting a perfect positive or negative correlation (Lovell et al. 2007). Spearman rank correlation coefficients (hereafter, ρ) were calculated in SAS Proc Corr (SAS Institute, Inc. 2007). For each taxa, we combined variables into logical groupings based on taxa and metric type (e.g., richness, abundance, etc.). For each group of metrics, we averaged ρ . Years (2007–2009) were analyzed separately. Definitions and summary statistics for all plant, butterfly, and bird metrics involved in correlation analyses are in Tables S4–S6 in Supplemental Information.

Because the literature on surrogates lacks a consensus on a minimum ρ (correlation strength) for use as a surrogate (Su et al. 2004; Lovell et al. 2007), we used multiple ρ values for evaluating correlations. Lovell et al. (2007) propose a relatively stringent minimum ρ -value of 0.75 to determine suitable (i.e., strong) correlations because this ensures that surrogate metrics (i.e., butterfly metrics) would represent 75 % of the target (i.e., bird or plant metrics). In contrast, Swengel and Swengel (1999) and Pearman and Weber (2007) consider correlations where $\rho \geq 0.5$ to be suitable surrogates. Reflecting this lack of consensus, we considered correlations where $\rho \geq 0.75$ (absolute value of ρ) to be suitable surrogates, correlations where $\rho \geq 0.5$ but ≤ 0.75 to be marginally suitable, and correlations where $\rho \leq 0.5$ to be unsuitable.

Results

Were disturbance butterflies correlated with birds?

Out of 168 pairwise correlations between disturbance butterfly species metrics and various bird metrics, only five

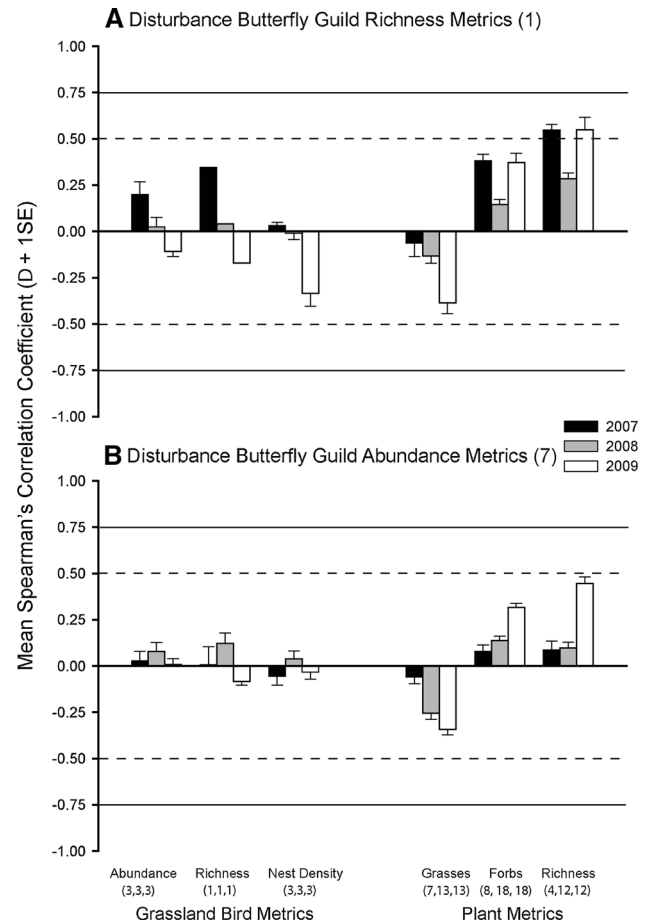


Fig. 1 Mean Spearman's ρ (SE) for disturbance butterfly guild species richness (**a**) and abundance metrics (**b**) with bird and plant metrics on grassland buffers in Clay County, Mississippi, 2007–2009. Number of bird and plant metrics in each category and year are listed in *parentheses*

were marginally suitable ($\rho \geq 0.5$ but ≤ 0.75) and none were suitable ($\rho \geq 0.75$) (Fig. 1; Table S7 in Supplemental Material). With few exceptions, mean ρ for disturbance butterfly metrics with bird metrics were low (between 0.25 and -0.25 , see Fig. 1; Table S7) and highly variable between years (even switching directions in many instances). Disturbance butterfly species richness was not a suitable surrogate for any bird metric and was inconsistently related among years. Pearl crescent abundance was a marginally suitable indicator for grassland bird metrics in 2007 and 2008, but not 2009 (Fig. 2; Table S7). Disturbance butterfly metrics were unsuitable surrogates for all nest density metrics in all years.

Were grassland butterflies correlated with birds?

All of the 63 pairwise correlations between grassland butterfly metrics and bird metrics were unsuitable

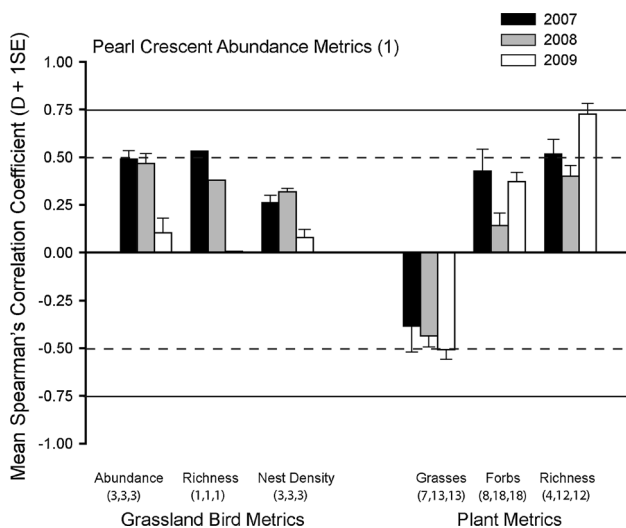


Fig. 2 Mean Spearman's ρ (SE) for pearl crescent abundance with bird and plant metrics on grassland buffers in Clay County, Mississippi, 2007–2009. Number of bird and plant metrics in each category and year are listed in parentheses

indicators (Fig. 3; Table S7). Correlations were generally weak (ρ between 0.10 and -0.10), and direction of the correlation varied among years (Fig. 3).

Were disturbance butterflies correlated with plants?

Out of the 840 pairwise correlations between disturbance butterfly metrics and plant metrics, 27 were suitable (3 %) and 176 (21 %) were marginally suitable (Fig. 1; Table S7). Correlations between grass metrics and disturbance butterfly metrics were generally negative, but correlations between forb and richness metrics were generally positive (Fig. 1). Disturbance species richness was generally more highly correlated to plant metrics compared to disturbance butterfly abundance metrics. Of the individual disturbance species metrics, pearl crescent had the greatest number of both suitable (5) and marginally-suitable (13) correlations (Fig. 2; Table S7) with plant metrics.

Were grassland butterflies correlated with plants?

Out of 315 pairwise correlations between grassland butterfly abundance metrics and plant metrics, 30 were marginally suitable (<10 %), and one was suitable (Fig. 3; Table S7). Similar to disturbance butterfly metrics, correlations between grass metrics and grassland butterfly metrics were generally negative, but correlations between forb and richness metrics were generally positive (Fig. 3). Grassland butterfly metrics were less strongly correlated to plant metrics than were disturbance butterfly metrics (Fig. 3; Table S7).

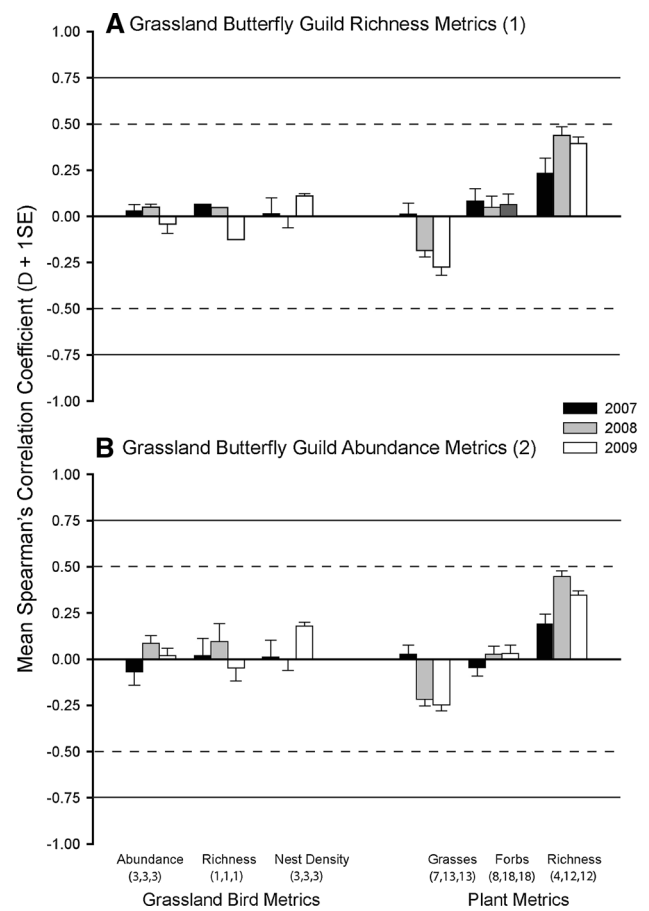


Fig. 3 Mean Spearman's ρ (SE) for grassland butterfly species richness (a) and abundance metrics (b) with bird and plant metrics on grassland buffers in Clay County, Mississippi, 2007–2009. Number of bird and plant metrics in each category and year are listed in parentheses

Discussion

Butterfly–bird correlations

Neither disturbance nor grassland butterfly metrics were suitable surrogates for birds in recently established semi-natural grasslands. Additionally, direction of correlations (positive or negative) was not consistent across the 3 years of our study, making use of butterflies as surrogates of birds in assessing establishment of semi-natural grasslands inappropriate. Although abundance and richness may not always be suitable surrogates (Ricketts et al. 1999; Su et al. 2004), reproductive metrics have rarely been investigated. We included grassland bird nest density metrics as a basic measure of reproductive effort (which should be better correlated to habitat quality than abundance) in our analysis, but correlations were also weak and inconsistent between years (mean $\rho = -0.045$ to 0.155).

In contrast to our results, Pearman and Weber (2007) observed a strong correlation between species richness of common butterflies (comparative to disturbance guild in our study) and common birds using data from a regional-scale monitoring program that included a range of ecosystems (i.e., Swiss national Biodiversity Monitoring Program; Pearman and Weber 2007). Butterfly–bird surrogates may show excellent representation at regional or landscape scales, yet demonstrate no correlation at a local scale, or vice versa (Reyers et al. 2002; Lombard et al. 2003). Our study was conducted in one habitat type within a single landscape (all buffers were contained within a 5-km radius circle), suggesting that butterflies may not be useful as surrogates to assess patches of conservation practices within single landscapes. Working at a scale more similar to ours, Swengel and Swengel (1999) found that prairie-specialist butterflies correlated with three grassland songbirds, but less than suitable similar to our results ($\rho \approx 0.3$ – 0.5). Also, we worked 3–5 years from establishment of grassland habitat, so butterfly and bird communities may not have yet completed colonized these new grasslands. But, even if bird–butterfly correlations increased with more time since establishment, that may be too late to evaluate establishment success.

Butterflies and birds may not be correlated for reasons other than (or in addition to) those stated above. One potential reason for the lack of correlations is that butterflies and birds have distinct habitat needs and may respond to habitat at different spatial scales. Availability of host and nectar plants in relatively small habitat patches is important to butterflies (Opler 1981; Opler and Krizek 1984; Moffat and McPhillips 1993; Swengel and Swengel 1998), whereas suitable habitat for breeding, nesting, and foraging in a relatively larger area is important to birds (Swengel and Swengel 1998). Also, localized events (e.g., habitat loss, hay field harvesting, pesticide drift) may have a greater negative impact on butterfly communities compared to bird communities due to their smaller size and sensitivity to habitat changes (Blair 1999; Debinski et al. 2001).

Butterfly–plant correlations

Butterfly metrics showed some potential as surrogates for plants in semi-natural grassland buffers. As predicted, abundance and species richness of butterflies (from disturbance and grassland guilds) were positively and consistently correlated with forb metrics and plant species richness metrics. Several butterfly abundance metrics (i.e., total abundance, disturbance butterfly abundance, cloudless sulfur abundance, pearl crescent abundance) had suitable ($\rho \geq 0.75$) correlations with plant species richness and forb metrics, although only 1 butterfly metric was suitable all 3 years (i.e., pearl

crescent abundance with plant species richness and forb richness, Table S7). Correlations were generally negative with grass metrics indicating that even grassland butterflies may not be suitable indicators of establishment success where grass establishment is an important end-point. However, suitable and positive correlations between butterflies and forbs suggests potential for surrogate relationships when establishment of abundant and diverse forb communities is a conservation goal (sensu Shepherd and Debinski 2005; Pearman and Weber 2007). Positive correlations with forbs (e.g., availability of nectar plants) may be consistent vegetative predictors of butterfly richness and abundance in many systems (Stoner and Joern 2004; Shepherd and Debinski 2005; Vogel et al. 2010). Therefore, abundance of nectar-rich forbs may have been driving the butterfly community (at least abundance of adults), thus causing the positive correlations between butterflies and forbs and between butterflies and plant species richness.

Pearl crescent correlations with birds and plants

The pearl crescent butterfly stood out from other butterfly metrics because it had consistent, positive correlations with grassland bird abundance metrics, particularly in 2007 and 2008. However, even though this species had the greatest average ρ -values compared to other butterfly metrics, ρ was never at or above the 0.75 suitability level for birds, and only a few correlations were marginally suitable ($\rho \geq 0.5$ but ≤ 0.75 ; Table S7). This suggests that pearl crescent and grassland birds may respond similarly to grassland habitat and other environmental variables, but that the correlations may not be strong or consistent enough to use pearl crescent as a surrogate for grassland birds in semi-natural grassland buffers.

The pearl crescent had suitable ($\rho > 0.75$) positive correlations with forb metrics and plant species richness metrics. Pearl crescents use various species of asters (*Aster* spp.) as host plants. Asters, milkweeds, thistles, and sunflowers are preferred nectar sources (Opler and Krizek 1984; Swengel 1996) and were abundant in buffers and across the study landscape. Though generally considered a disturbance-tolerant or generalist species (Reeder et al. 2005; Shepherd and Debinski 2005; Vogel et al. 2010), Ries et al. (2001) consider pearl crescent habitat sensitive. More study is needed to determine the specific habitat features to which pearl crescent respond to determine if they are a suitable surrogate for bird and plant diversity in semi-natural grasslands across the pearl crescent range.

Conclusions

Semi-natural grasslands provide important habitat for a number of prairie-associated species. Our results show that

butterflies should not be used as surrogates for grassland bird metrics, non-grassland bird metrics, or nest density in semi-natural grassland buffers in the Southeast, at least when used to assess recently established patches within a landscape. Butterflies did have consistent positive correlations with plant species richness and forb metrics, as well as consistent negative correlations with grass metrics, but these correlations were still generally smaller than what is considered suitable to serve as surrogates (Lovell et al. 2007). The only butterfly metric with strong positive correlations with plant metrics was the pearl crescent, which might be a suitable indicator of grassland restoration success, particularly if abundance and richness of forbs is a management objective. However, because of the negative correlations between butterflies and grass metrics, butterflies could not serve as indicators of establishment success if establishment of grass dominated communities is the management objective. Areas of future research should focus on gaining a better understanding of life-history traits of grassland butterfly species and determining abiotic and biotic factors which contribute to year-to-year variability in their populations. Also, use of multivariate analysis and ordination to determine which environmental variables inclusively impact butterflies, plants, and birds would be helpful.

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