Butterflies and Continuous Conservation Reserve Program Filter Strips: Landscape Considerations

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Abstract

Filter strips or buffers are areas of grass or other perennial herbaceous vegetation established along waterways to remove contaminants and sediments from agricultural field runoff. In the heavily cultivated regions of the Midwestern United States, these buffer zones established under the Farm Bill provide important habitat for wildlife such as butterflies. The question of how the landscape context of these plantings influences their use has not been adequately researched. We used multiple regression and Akaike's Information Criteria to determine how habitat width and several landscape-level factors (i.e., landscape composition [total herbaceous cover, amount of developed area, and amount of wooded cover] and configuration [herbaceous edge density]) influenced the abundance and diversity of the butterfly community using filter strips in southwestern Minnesota, USA. Habitat-sensitive butterfly abundance and all richness and diversity measures were positively correlated with filter-strip width. Butterfly abundance was negatively associated with the amount of developed areas (cities, towns, and roads) within the area of a 1-km radius (3.14 km^2) surrounding the sites. Percentage of wooded cover in the landscape was an important variable explaining individual species abundance, although the direction of the relationship varied. Our finding that landscape context influences butterfly use of filter strips highlights the importance of landscape-level approaches to wildlife conservation in agroecosystems.
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In the past 150 years, the Midwestern United States has undergone a dramatic conversion from tallgrass prairie to row-crop agriculture (Samson and Knopf 1994). Intensified land use has caused increased soil erosion and loss of wildlife habitat. The Conservation Reserve Program (CRP), authorized by the 1985 Farm Bill, has facilitated the re-establishment of natural vegetation, including grassland in the Midwest, by reimbursing farmers for taking land out of production and planting perennial vegetation in place of crops. The 1996 Farm Bill authorized a corollary to this program, the Continuous Conservation Reserve Program (CCRP), so-called because it allows producers to enroll on a continuous basis, instead of during a competitive sign-up period like the CRP. The CCRP targets highly erodible areas that are generally small in acreage and mostly linear in configuration. Examples of practices eligible for reimbursement under CCRP include riparian forest buffers, filter strips, grassed waterways, shelterbelts, and wetland buffers. This study focuses on filter strips, which comprise the largest proportion of the acreage enrolled under the CCRP, accounting for about 36% of total CCRP acreage (Farm Service Agency [FSA] 2005). In particular, filter strips are areas of grass or other perennial herbaceous vegetation established along waterways to remove contaminants and sediments from agricultural field runoff (Schmitt et al. 1999,

Natural Resource Conservation Service [NRCS] 2003). An additional purpose of filter strips is to "restore, create, or enhance herbaceous habitat for wildlife and beneficial insects" (NRCS 2003:393-1).

This paper addresses a functional gap in research on the effects of American farm conservation programs on wildlife. Although the response of vertebrate organisms to CRP has been relatively well studied, especially for birds (Johnson and Schwartz 1993, Best et al. 1997, Delisle and Savidge 1997, Knoot 2004, Davros 2005, Henningsen and Best 2005), mammals (Chapman and Ribic 2002), and herpetofauna (Semlitsch and Bodie 2003, Knoot 2004), there is a significant gap in research relative to insect responses to farm conservation programs, especially from the perspective of landscape-level effects (Clark and Reeder 2005, Farrand and Ryan 2005).

Investigators who have studied insect use of farm-program plantings in the United States have focused primarily on local-level effects. Reeder et al. (2005) examined the influence of local habitat factors on butterfly use of filter strips, while Benson (2003) examined the effects of burning and disking on insect diversity in Wetlands Reserve Program floodplain easements in east-central Iowa, USA. Davros (2005) studied a wider array of insect taxa in Minnesota, USA, filter strips than Reeder et al., but again only included a local-level analysis. Insect community studies that have included landscape-level analyses have focused primarily on remnant grasslands rather than conservation buffers (Sutcliffe et al. 2002, Tscharntke et

al. 2002, Weibull and Ostman 2003, Bergmann et al. 2004, Skibbe 2005).

In Midwestern row-crop agriculture settings where there is little remaining remnant grassland habitat, filter strips are important components of the contemporary landscape that have the potential to provide habitat for grassland-dependent wildlife (U.S. Department of Agriculture [USDA] 1997). We previously documented the influence of local habitat features on butterfly use of filter strips; for a detailed discussion of the importance of local effects, including vegetative composition and nectar availability, see Reeder et al. (2005). The best models to explain overall butterfly abundance included the percent cover of forbs and the number of flowering stems within the buffer strips. The models that best explained abundances of large, habitat-sensitive butterflies such as *Cercyonis pegala* and *Speyeria idalia* included the height and vertical density of vegetation. However, given the effects of landscape on insect communities quantified in other systems described above, we wanted to also examine the potential of filter strips as butterfly habitat from a landscape perspective.

Butterflies are a valuable group to use as indicators of the effects of agroecological management on insect pollinators because they are diverse; approximately 50 butterfly species can occur in these habitats. They also are easier to identify compared with other insect groups that require additional hours of identification in the lab. Understanding how landscape context influences insects in filter strips is critical to a broader comprehension of the effects of farm conservation programs on important wildlife. The information gathered in this study may be used to help guide planning and implementation of USDA conservation buffers to optimize wildlife conservation benefits.

Our objectives were to quantify the habitat components of the landscape surrounding the filter strips within an area of 1-km radius (3.14 km^2) and to identify the habitat components most strongly correlated with butterfly distribution patterns. We included filter-strip width as a local-level variable to compare its importance relative to landscape-level variables. We used width as our local metric because width rather than area may be the limiting factor for wildlife in these habitats; strip-cover habitats may be many miles long but can vary substantially in width along their course (Best 2000). We analyzed butterfly responses from the community perspective (abundance, richness, diversity) as well as from an individual species perspective when sample size permitted. We also examined responses by dividing the butterfly community into 2 guilds: disturbance-tolerant species and habitat-sensitive species. We predicted that the amount of herbaceous cover and the amount of developed areas in the landscape would be important variables explaining diversity and abundance of butterflies using filter strips. We expected disturbance-tolerant species to be positively associated with landscapes that had a higher level of fragmentation, whereas habitat-sensitive species would be negatively associated with fragmentation in the landscape. We also predicted that filter-strip width would

have a positive impact on the abundance of habitat-sensitive butterflies and on the diversity of the butterfly community in our sites.

Study Area

At the time of the study, Minnesota had ~62,322 ha (154,000 acres) of filter strips (Farm Service Agency 2005). Our research focused on filter strips in a 5-county area in southwest Minnesota (Jackson, Cottonwood, Watonwan, Nobles, and Brown counties), which covered portions of the Minnesota River and Des Moines River watersheds. Land in the area was primarily privately owned and was dominated by corn and soybean production.

Study-Site Selection
We chose 38 sites from a pool of potential filter strips in this 5-county area based upon the following 4 criteria: 1) filter strips were ≥3 years old to allow for establishment of vegetation, 2) sites had <15% trees or shrubs along the waterway, 3) filter strips were ≥350 m in length, and 4) sites were ≥1 km apart. Selected sites included filter strips buffering one or both sides of a waterway. All sites were bordered laterally by crops such as corn, soybeans, or wheat except for one site which was bordered by a gravel road. Our sites spanned a range of widths allowed under both CCRP (8–36 m) and Minnesota's Conservation Reserve Enhancement Program (36–148 m), a program that provides incentives for the widening of filter strips. Based on seeding plans filed with the NRCS, we initially categorized our sites as dominated by non-native plant species ($n = 14$), dominated by native plant species ($n = 11$), or switchgrass-dominated (*Panicum virgatum*; $n = 13$). Smooth brome (*Bromus inermis*), reed canarygrass (*Phalaris arundinacea*), and quackgrass (*Agropyron repens*) were common in non-native filter-strip sites. Among native sites Canada wild rye (*Elymus canadensis*), Indiangrass (*Sorghastrum nutans*), and big and little bluestem (*Andropogon* spp.) were the most common species observed. Common forbs observed in all filter strips included Canada thistle (*Cirsium canadense*), alfalfa (*Medicago sativa*), and sweet clover (*Melilotus* spp.). Though each landowner individually managed filter strips, sites used in this study did not differ significantly in their management. None were treated with insecticide or fertilized; usual techniques for weed control were infrequent spot mowing and spot spraying.

Methods

Transect Establishment and Study-Site Dimensions
Each site had one survey transect. Each transect, marked with pin flags, was 200 m long × 5 m wide. We placed transects halfway between the waterway and the agricultural field, and they began at least 50 m from any roadway adjacent to the strip. We computed filter-strip width by averaging width measurements taken at 5 equidistant points along the length of each transect and one additional point 25–50 m beyond each end of the transect.

Landscape Characteristics

We downloaded 2003 color aerial photos (2-m resolution) for each county from Minnesota's Land Management Information Center (LMIC) website (see acknowledgments for website information). Using ArcView Global Information System 3.3 (Environmental Systems Research Institute, Redlands, California) we hand-digitized each map feature within an area of 1-km radius (3.14 km^2) of the midpoint of each site transect. We then classified each feature to a habitat category, and later ground-truthed a subset of polygons for accuracy. Classifications used were as follows: 1) herbaceous habitat: state- or federally owned wildlife management areas, pastures, hayfields, CRP fields, small-grain fields (e.g., wheat, rye), and herbaceous strip cover (roadsides, grassed waterways, filter strips, semi-permanent streams with herbaceous cover, terraces, fencerows); 2) row crop: corn or soybean fields; 3) wooded: woodlands, wooded stream corridors, woodlots, wooded roadsides, wooded fencerows; 4) wetlands and open water: wetlands, lakes, and large, fast-flowing rivers; and 5) developed areas: towns, cities, and all roads. We calculated percent landscape composition of each category for each site. We used the Patch Analyst extension in ArcView to quantify total edge density and herbaceous edge density (m of perimeter/ha of habitat category) to help describe the level of fragmentation in our landscapes (Fletcher and Koford 2002).

Butterfly Abundance, Richness, and Diversity

We conducted 2 butterfly surveys in 2002 (5–22 Jul and 22 Jul–15 Aug) and in 2003 (16 Jun–12 Jul and 15 Jul–11 Aug). Surveys coincided with periods of greatest butterfly activity; we conducted them on warm ($\geq 18°C$), sunny ($<60\%$ cloud cover), and calm (sustained winds <16 km/hr) days between 0900–1730 hours. We modified butterfly-survey methods after Thomas (1983). Observers walked transects at a speed of 10 m/minute; survey effort was constant at 20 minutes/transect. We identified all butterflies within a 5 × 5-m visual field in front of the observer and recorded their behavior. We stopped timers for capture and recording. We captured any butterflies that observers were unable to identify in the field using a net and transported them to the lab in a glassine envelope for identification. To minimize observer bias, we rotated surveyors at each site throughout the season.

Statistical Analyses

Prior to analysis, variables were natural-log or square-root transformed as necessary to improve normality and homogeneity of variances.

Landscape characteristics.—We computed means and standard errors for each landscape metric. The wetlands–open water variable had a highly skewed distribution that could not be transformed to meet model assumptions, so the variable was dropped from subsequent analyses. Percent row-crop cover was highly correlated with total herbaceous cover, and total edge density was highly correlated with herbaceous edge density. We dropped both percent row-crop cover and total edge density from further analyses to reduce problems of multicollinearity (Quinn and Keough

Table 1. Numbers of individuals of each butterfly species observed during transect surveys of 38 filter strips during the summers of 2002 and 2003 in southwestern Minnesota, USA. Butterflies were categorized into guilds using information on habitat, foodplants, and hostplants from Opler and Krizek (1984), Scott (1986), Glassberg (1999), and Ries et al. (2001). Butterflies occurring commonly in anthropogenically disturbed areas are classified as disturbance-tolerant (DT); species requiring unaltered habitat during any part of their life cycle are classified as habitat-sensitive (HS).

Species	No. of individuals	Guild category
Everes comyntas (Eastern tailed-blue)	360	DT
Danaus plexippus (Monarch)	234	DT
Colias eurytheme/philodice (Orange/Clouded sulphurs)[a]	170	DT
Ancyloxypha numitor (Least skipper)	73	DT
Speyeria idalia (Regal fritillary)	68	HS
Vanessa cardui (Painted lady)	53	DT
Cercyonis pegala (Common wood-nymph)	51	HS
Vanessa atalanta (Red admiral)	42	DT
Pieris rapae (Cabbage white)	14	DT
Satyrodes eurydice (Eyed brown)	14	HS
Anatrytone logan (Delaware skipper)	9	HS
Pholisora catullus (Common Sootywing)	8	DT
Papilio polyxenes (Black swallowtail)	6	DT
Speyeria cybele (Great spangled fritillary)	5	HS
Papilio glaucus (Eastern tiger swallowtail)	3	n/a[b]
Pyrgus communis (Common checkered-skipper)	3	HS
Limenitis archippus (Viceroy)	2	DT
Lycaena hyllus (Bronze copper)	2	HS
Polites peckius (Peck's skipper)	2	DT
Polites themistocles (Tawny-edged skipper)	2	DT
Celastrina argiolus (Spring azure)	1	HS
Limenitis arthemis asyntax (Red-spotted purple)	1	DT
Phyciodes tharos (Pearl crescent)	1	DT
Polites mystic (Long dash)	1	HS
Polites origines (Crossline skipper)	1	HS
Speyeria aphrodite (Aphrodite fritillary)	1	HS
27 Total Species	1,127[c]	

[a] *Colias spp.* were combined due to initial identification uncertainty.
[b] Species adapted to woody habitats were not classified as disturbance-tolerant or habitat-sensitive.
[c] Does not include individuals not identified to species.

2002:127). We used all remaining variables in the model-selection procedures described below.

Butterfly abundance, richness, and diversity.—To better understand the relationship between filter strips and the butterfly community, we separated the butterfly species into 2 guilds before conducting the analyses: disturbance-tolerant and habitat-sensitive (Table 1). We categorized each species based upon information presented in Opler and Krizek (1984), Scott (1986), Glassberg (1999), Ries et al. (2001), and Reeder et al. (2005). Disturbance-tolerant butterflies are species that commonly can be found in areas altered by humans such as suburban lawns and gardens. Thus, they are effectively tolerant of removal of the native vegetation. Habitat-sensitive species have more specific requirements for habitat and vegetation composition and structure, either due to larval hostplant requirements or the

needs of other life stages and are often found only in relatively natural areas (i.e., areas with native vegetation). We calculated butterfly abundance and Shannon-Weiner diversity (H') as means of all rounds, while we tallied species richness across rounds to arrive at a total number of species observed at each site over both years. We also used the abundances of species with a sufficient sample size (>50 observations) as a response variable in the analyses.

We analyzed the abundance, richness, and diversity of butterflies with respect to filter-strip width, percent cover of various elements of the landscape (herbaceous habitat, wooded land, and developed areas), and herbaceous edge density within the landscape. We used model-selection procedures to evaluate the variables important in determining butterfly community responses. We ran all combinations of variables (not including interactions) using multiple linear regression, then evaluated each model using Akaike's Information Criterion adjusted for small sample sizes (AIC$_c$) following Burnham and Anderson (2002). We considered models to be competing if they were within a ΔAIC$_c$ (i.e., AIC$_{ci}$ − minAIC$_c$) of 2. We assessed model-selection uncertainty by evaluating ΔAIC$_c$ values, Akaike weights (w_i), and model-averaged parameter estimates (Burnham and Anderson 2002). We considered variables with a model-averaged parameter estimate of $>\pm0.10$ to be important.

Results

Landscape Characteristics

Row crops dominated our landscapes, covering an average of 85% of the landscape (range = 68–94%) within the 3.14-km^2 area around our sites. Herbaceous cover was the next-highest cover type, covering 9% of the landscape (range = 4–25%). Developed areas made up 1% (range = 0–15%), wooded areas 0.7% (range = 0–4%), and open water–wetlands 0.1% (range = 0–12%) of the landscape. Average herbaceous edge density was 64 m/ha (range = 40–105 m/ha).

Butterfly Abundance, Richness, and Diversity

We observed 1,227 individuals of 27 butterfly species (Table 1). Our models explained some variation (R^2 range: −0.02–0.21) in butterfly abundance, richness, and diversity, although models for some measures were weak (Table 2). Butterfly use of filter strips was influenced by both local- and landscape-level variables. At the local level, all response variables were positively influenced by filter-strip width (Table 3). Habitat-sensitive butterflies, all richness measures, and Shannon-Weiner diversity strongly increased with filter-strip width. Individual species that responded strongly and positively to filter-strip width were *Cercyonis pegala* (common wood-nymph) and *Vanessa cardui* (painted lady). The most important landscape-level variables were the percent cover of developed and wooded areas within the area of a 1-km radius (3.14 km^2) surrounding our sites (Tables 2 and 3). Abundance and richness of all species and habitat-sensitive species, Shannon-Weiner index of diversity, and abundance of *Speyeria idalia* (regal fritillary) decreased with

the percent cover of developed areas. Abundance of *Colias* spp. (orange or clouded sulphurs), *Danaus plexippus* (monarch), and *S. idalia* increased with the amount of wooded cover in the landscape, while abundance of *Ancyloxypha numitor* (least skipper) was negatively associated with wooded cover. Overall, most variables showed a positive association with the amount of wooded cover. Abundance of *Everes comyntas* (eastern tailed-blue) was strongly and negatively associated with the amount of herbaceous cover in the landscape. Herbaceous edge density was negatively correlated with the abundance of *V. cardui* (Table 3).

Discussion

The importance of filter-strip width is reiterated in many of the models, and confirms the responses that we examined when describing the butterfly community at the local level (Reeder et al. 2005). Width was consistently positively associated with most of our butterfly response variables, signifying the potential conservation value of wider filter strips. In a companion study, Davros (2005) reported invertebrate taxa richness and abundance to be positively correlated with filter-strip width. Studies of other taxa (e.g., birds) have also reported positive relationships between abundance or richness and conservation-buffer width (Best 2000, Knoot 2004, Davros 2005, Henningsen and Best 2005). Filter-strip width also influences the total area of natural vegetation. To distinguish the effects of these 2 factors, we assessed the total herbaceous cover in the landscape within the 1-km-radius area (see below).

As observed in other landscape studies of butterflies in agroecosystems (e.g., Weibull and Ostman 2003, Bergmann et al. 2004, Skibbe 2005), we found that features in the surrounding landscape explained some of the variation in species distribution and abundance patterns. Although we did not examine landscape effects to the same spatial extent of Bergmann et al. (2004), we did find salient results, especially with respect to effects of width and percent cover of developed areas.

The predominance of the developed area variable in the models is striking. This variable appears in the best models for all abundance measures, total species richness, habitat-sensitive species richness, Shannon-Weiner diversity of the entire community, and abundance of *S. idalia*. The consistently negative association between the amount of developed areas in the landscape and butterfly abundance, richness, and diversity suggests that these areas have negative impacts on butterfly occurrences. While our development variable is composed of cities, towns, and roads, it is primarily dominated by roads in the southern Minnesota landscape because relatively few of our sites are within 1 km of a town. The negative association between butterfly abundance and richness and percentage of developed areas may be due to mortality associated with roads. Southwestern Minnesota, like other areas of the Midwest, is composed of a grid of square-mile sections demarcated by roads. Ries et al. (2001) found that roadside

Table 2. Best landscape models (i.e., models with ΔAIC$_c$ < 2 and highest w_i) for butterfly abundance, richness, and diversity in 38 United States Department of Agriculture filter strips in southwestern Minnesota, USA, Jun–Aug 2002 and 2003.[a]

Butterfly variable	K[b]	AIC$_c$	ΔAIC$_c$	w_i	Adj. R^2	Variables[c] in model
Abundance		—				
All species	2	−36.6	0.00	0.18	0.04	−Develop
	3	−34.82	1.78	0.07	0.03	AveWidth − Develop
	2	−34.81	1.79	0.07	−0.01	AveWidth
Disturbance-tolerant	2	−30.79	0.00	0.13	0.02	−Develop
	2	−29.96	0.84	0.09	0.00	−HED
	2	−29.89	0.90	0.08	0.00	AveWidth
	2	−29.25	1.54	0.06	0.02	Wooded
	3	−29.25	1.54	0.06	0.02	AveWidth − Develop
Habitat-sensitive	3	115.24	0.00	0.10	0.09	AveWidth − Develop
	3	115.39	0.15	0.09	0.08	TotHerb − Develop
	2	115.46	0.23	0.09	0.05	AveWidth
	2	115.60	0.36	0.08	0.05	−Develop
	2	116.10	0.86	0.06	0.03	TotHerb
	3	116.33	1.10	0.06	0.06	−Develop + HED
	4	116.51	1.27	0.05	0.09	AveWidth − Develop + HED
	4	116.54	1.30	0.05	0.09	AveWidth + TotHerb − Develop
Ancyloxypha numitor	2	132.69	0.00	0.16	0.02	−Wooded
	2	134.03	1.34	0.08	−0.01	AveWidth
	3	134.28	1.59	0.07	0.02	AveWidth − Wooded
	2	134.36	1.67	0.07	−0.02	−TotHerb
Colias spp.	2	−14.54	0.00	0.25	0.14	Wooded
	3	−13.32	1.22	0.14	0.14	Wooded + HED
Cercyonis pegala	2	129.20	0.00	0.16	0.08	AveWidth
	3	130.37	1.16	0.09	0.08	AveWidth − Wooded
	3	130.89	1.68	0.07	0.07	AveWidth + TotHerb
Danaus plexippus	2	106.90	0.00	0.18	0.06	Wooded
	3	108.49	1.59	0.08	0.05	AveWidth + Wooded
	3	108.53	1.62	0.08	0.05	TotHerb + Wooded
Everes comyntas	2	75.88	0.00	0.24	0.13	−TotHerb
	3	76.84	0.96	0.15	0.14	−TotHerb − Develop
Vanessa cardui	2	131.03	0.00	0.15	0.04	AveWidth
	3	131.83	0.80	0.10	0.05	AveWidth − HED
Speyeria idalia	2	128.81	0.00	0.15	0.06	−Develop
	3	129.59	0.78	0.10	0.07	−Develop + Wooded
	2	130.13	1.33	0.08	0.03	Wooded
Richness						
All species	3	61.95	0.00	0.19	0.15	AveWidth − Develop
	2	62.27	0.32	0.16	0.11	AveWidth
Disturbance-tolerant	2	36.82	0.00	0.13	0.03	AveWidth
	2	37.17	0.35	0.11	0.02	Wooded
	3	37.32	0.50	0.10	0.05	AveWidth + Wooded
Habitat-sensitive	3	3.45	0.00	0.29	0.21	AveWidth − Develop
Diversity						
Shannon-Weiner	3	−131.27	0.00	0.12	0.12	AveWidth − Develop
	2	−130.58	0.68	0.09	0.07	AveWidth
	2	−130.03	1.24	0.07	0.06	−Develop
	4	−129.94	1.33	0.06	0.12	AveWidth − Develop + Wooded
	3	−129.82	1.44	0.06	0.09	AveWidth + Wooded
	3	−129.76	1.51	0.06	0.08	TotHerb − Develop

[a] Abbreviations: AIC$_c$ = Akaike's Information Criterion adjusted for small sample size; w_i = Akaike weight; Adj. = adjusted.
[b] K indicates the number of parameters used in the regression model (+1).
[c] Explanatory variables: AveWidth = average width of filter strip as determined by on-the-ground measurements; TotHerb = total amount of herbaceous cover in landscape (%); Develop = amount of all cities, towns, and roads in landscape (%); Wooded = amount of wooded cover in landscape (%); HED = total herbaceous edge density in landscape (m/ha).

plantings in Iowa could attract butterflies, but that roads, especially paved roads, pose a significant mortality risk to butterflies. They estimated the mortality risk for a butterfly crossing a road to be 7% for paved roads and 1% for gravel roads (Ries et al. 2001). Many of the roads in our study area are gravel, and, because many butterfly species display mud-puddling behavior, they may experience increased mortality

from congregating on the road. Skibbe (2005) also found *S. idalia* to be negatively associated with roads in Iowa.

Percent cover of wooded habitat in the landscape may be more representative of riparian or degraded woodland cover within the area of a 1-km radius surrounding our sites. We specifically chose filter strips with few if any trees, so any wooded habitat components were not within the filter strips

Table 3. Model-averaged parameter estimates for variables in regression models of butterfly abundance, species richness, and diversity in 38 United States Department of Agriculture filter strips in southwestern Minnesota, USA, Jun–Aug 2002 and 2003. The parameter estimates are weighted based on the sum of Akaike weights (w_i) over candidate models in which the variable occurred. Numbers in bold are $> \pm 0.10$ and were considered important.

Butterfly variable	AveWidth[a]	Landscape variables[b]			
		TotHerb	Develop	Wooded	HED
Abundance					
All species	0.05	0.00	**−0.15**	0.03	0.00
Disturbance-tolerant	0.07	−0.02	−0.09	0.03	−0.06
Habitat-sensitive	**0.12**	0.09	**−0.18**	0.01	0.04
Ancyloxypha numitor	0.05	0.03	−0.01	**−0.12**	0.00
Colias spp.	0.00	−0.02	−0.02	**0.34**	0.09
Cercyonis pegala	**0.20**	0.08	−0.05	−0.08	0.01
Danaus plexippus	0.04	0.05	0.03	**0.19**	0.00
Everes comyntas	0.00	**−0.34**	−0.07	−0.01	−0.01
Vanessa cardui	**0.15**	0.06	0.01	0.00	**−0.11**
Speyeria idalia	0.05	0.01	**−0.18**	**0.10**	0.00
Richness					
All species	**0.31**	−0.02	**−0.13**	0.03	−0.01
Disturbance-tolerant	**0.14**	−0.02	−0.03	**0.11**	−0.01
Habitat-sensitive	**0.32**	0.00	**−0.25**	−0.01	0.01
Diversity					
Shannon-Weiner	**0.17**	0.06	**−0.18**	0.06	0.02

[a] Average width of filter strips as determined by on-the-ground measurements.
[b] Landscape variables: TotHerb = total amount of herbaceous cover in landscape (%); Develop = amount of all cities, towns, and roads in landscape (%); Wooded = amount of wooded cover in landscape (%); HED = total herbaceous edge density in landscape (m/ha).

themselves. Strong relationships between disturbance-tolerant species and wooded habitats may result from availability of mud-puddling sites or tolerance of degraded habitats. Because *Colias* spp. make up a large percentage of the abundance of disturbance-tolerant species, this may explain the positive association between disturbance-tolerant species richness and wooded habitat. In addition, some butterfly species use trees as perching sites in the evenings. *Danaus plexippus* is a case in point, so it is not surprising that it responded positively to the percent wooded cover within the landscape we examined. *Speyeria idalia* may be using wooded riparian areas for mud-puddling. *Ancyloxypha numitor* responded negatively to wooded cover. It is a species that prefers open habitats and, thus, may be avoiding the shade that wooded areas provide.

Herbaceous edge density was used as a measure of habitat fragmentation. We expected that disturbance-tolerant species would be associated with high levels of herbaceous edge density. As expected, *Colias* spp. (both disturbance-tolerant species) showed weak but positive associations with herbaceous edge density. *Colias* species are the epitome of butterfly edge species in Midwestern landscapes and often are found along roadside edges. Because clover (*Trifolium repens*) is a hostplant for both *Colias* species and is found along roadsides, it is not surprising that these *Colias* species showed positive associations with edge habitats in this landscape. However, disturbance-tolerant species as a group and *V. cardui* specifically showed negative associations with herbaceous edge density. Thus, even disturbance-tolerant species may prefer less-fragmented patches.

We expected that total herbaceous cover would be an important landscape component for the butterfly community, as was found by Skibbe (2005). Total herbaceous cover does show up as a positive influence in competing models for habitat-sensitive abundance and Shannon-Weiner diversity. However, the model-averaged parameter estimates for each are weaker, indicating that this variable is not as important as other landscape variables in explaining habitat-sensitive abundance and overall diversity. Herbaceous cover also is weakly positively associated with individual species such as *D. plexippus* but strongly and negatively associated with *E. comyntas*. *Everes comyntas* is a small butterfly with rounded wings that uses the landscape on a very fine scale. As compared to *D. plexippus*, this less vagile species probably is much less affected by the larger landscape scale. These differing responses to landscape factors based upon species mobility are similar to the results found by Tscharntke et al. (2002).

Additional research is needed to clarify the relationships between wildlife communities in buffers and the amount of herbaceous cover in the surrounding landscape. Because our study area is heavily agricultural, herbaceous cover in our landscapes only ranged from 4–25% and was often linear in form. Only a small number of sites had >15% herbaceous cover in the surrounding area described by the 1-km radius. Butterfly responses to the amount of grassland habitat in the landscape may have been stronger if some of our sites had >50% herbaceous cover. Such a response to the amount of perennial cover in the landscape has been modeled for other taxa. For example, Clark et al. (2001) demonstrated that predicted response of pheasant (*Phasianus colchicus*) abundance in Iowa landscapes would not reach peak abundance until nearly 50% of the landscape was in perennial grassland. Because it is difficult to find areas with perennial grassland

covering such large portions of the landscape in our study region, comparable studies in other regions could provide important information about thresholds. Modeling approaches also could be undertaken to predict how many conservation program plantings would be necessary to create a persistent, positive change in wildlife population sizes in agricultural areas.

Management Implications

Filter strips are important tools for protecting water quality, but creation and maintenance of wildlife habitat also is an explicit goal of many buffer practices. Because buffer plantings provide a significant proportion of the habitat available to wildlife in heavily cultivated regions like the Midwest, it is crucial to understand how their utility to wildlife can be maximized. Based on our findings and on the results of our previous research on local variables, we recommend planting buffers to be as wide as possible, with diverse vegetative composition and structure to enhance wildlife benefits. The percent cover of forbs, number of forb stems in bloom, height, and vertical density of the vegetation all are important (Reeder et al. 2005). This vegetative diversity can provide both resources of nectar, and, if the plantings are especially diverse, may even provide host plants for the habitat-sensitive species.

Our finding that landscape variables such as percent wooded cover and percent developed areas help explain abundance, richness, and diversity of the butterfly community highlights the importance of broadening our understanding of how landscape variables affect wildlife in farm-program plantings. In addition, the influence of landscape variables on wildlife in buffers has repeatedly been demonstrated (Clark et al. 2001, Knoot 2004, Davros 2005), but many farm-bill programs currently are not set up to allow the geographic targeting of specific areas based on landscape features. This is beginning to change as the importance of landscape and watershed approaches has become better understood; some Conservation Reserve Enhancement Programs now target specific areas and landowners for enrollment to allow planning on a regional scale. To the extent that targeting is practical and does not unduly hinder participation in farm bill programs, we recommend that programs used to achieve wildlife conservation goals incorporate such landscape-oriented approaches.

Acknowledgments

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