



Factors affecting butterfly use of filter strips in Midwestern USA

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Abstract

Filter strips are areas of herbaceous vegetation planted between agricultural fields and streams. In 2002 and 2003, the butterfly community in filter strips of a variety of widths and vegetative compositions was studied. Transect surveys were used to quantify butterfly abundance and diversity and measured vegetative variables in conjunction with each butterfly survey round. Overall butterfly diversity (H') and abundance of habitat-sensitive butterflies were positively correlated with filter strip width. Using stepwise regression, the best models to explain butterfly abundance included the coverage of forbs and the number of ramets in bloom in the strips, and indicated positive relationships between forbs and the butterfly community ($R^2 = 0.33$ and 0.07 , respectively). The models that best explained abundances of large, habitat-sensitive butterflies included the height and vertical density of vegetation. The planting of forbs in filter strips is rare, but may be useful for providing food sources to butterflies.

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1. Introduction

Grassland in the Midwestern United States has been dramatically reduced in the past century as native vegetation was converted to rowcrop agriculture. In Minnesota, loss of tallgrass prairie has been estimated at 99.6% (Samson and Knopf, 1994). Federal land retirement programs, such as the Conservation Reserve

Program (CRP), have re-established millions of hectares of grassland in the Midwest (Heard, 2000). Under these programs, farmers can be reimbursed for removing portions of land from crop production to plant grasses. In 1996, the United States Department of Agriculture (USDA) initiated continuous enrollment CRP (United States Congress, 1996). Several types of linear buffer plantings are eligible under this program. Whereas buffers are being established primarily to improve water quality and to control soil erosion, additional benefits gained from buffers may include enhanced aesthetics and wildlife habitat (Heard, 2000).

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The assumption that higher densities of animals in a given habitat type indicate superior habitat quality can be misleading (Van Horne, 1983; Pulliam, 1988; Pulliam and Danielson, 1991). The idea that low-quality corridors could act as ecological traps has been proposed (Anderson and Danielson, 1997), suggesting the need to assess the quality of potential stepping stone habitat to identify possible risks as well as benefits. Predation risk to butterflies could be elevated in narrow strips of habitat if the predators' efficiencies or abundances are higher in these areas. Other researchers have shown that bird abundances are often greater in strip-cover habitat than in surrounding rowcrop fields (Best et al., 1995), and sometimes greater than in surrounding block-shaped grassland areas (Best, 2000). In soybean fields in Ohio, researchers found that aboveground arthropod predators were higher in grassy corridors than in adjacent soybean fields; the corridors may have even drawn in predators from the planted fields (Kemp and Barrett, 1989).

This research examined butterfly community composition in a variety of different filter strip widths and plant compositions. The objectives were to (1) quantify the abundance and diversity of butterflies in filter strips and (2) assess the influence of filter strip width and vegetative composition on butterfly abundance and diversity.

2. Methods

The research focused on filter strips in a five-county area in southwest Minnesota (Jackson, Cottonwood, Watonwan, Nobles and Brown counties), which cover portions of the Minnesota River and Des Moines River watersheds. This region is dominated by corn and soybean production. Land in the area is primarily privately owned; less than 5% of land in any of these counties is state-owned (Minnesota House of Representatives, 2003).

Categorization of filter strips fell into three general planting types based on the seeding plans filed with the Natural Resources Conservation Service (NRCS): non-native, switchgrass (*Panicum virgatum*)-dominated and diverse mixtures of native species. Fourteen non-native, 14 switchgrass and 15 native strips were selected for use. Forty-nine filter strips were used in this study, all of which had been established for 3–7

years. Selected filter strips were planted on both sides of the streams that they buffer, were >350 m long and were bordered laterally by crops such as corn, soybeans or wheat. Filter strips 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.

To reduce the number of confounding variables, only filter strips with either no trees or minimal numbers of trees growing in them were used. All trees present in the strips within 100 m of the transect were counted, and filter strips were placed into the following categories: no trees (30 strips), 1–10 trees (16 strips) or 11–50 trees (3 strips). A one-way analysis of variance (ANOVA) showed no difference in either the abundance ($F = 0.41$, $p = 0.66$) or the richness ($F = 1.17$, $p = 0.32$) of butterflies among the three categories.

Each site had one transect, and each transect, marked with pin flags, was 200 m × 5 m. Transects were placed in the middle of one side of each filter strip and began at least 50 m from any roadway adjacent to the strip. Butterfly surveys were timed to coincide with periods of greatest butterfly activity; they were conducted on warm ($\geq 18^\circ\text{C}$), sunny (<60% cloud cover) and calm (sustained winds <16 km/h) days between 09:00 and 17:30 h. Butterfly survey methods followed a modification of Thomas (1983). Transects were walked at a speed of 10 m/min; survey effort was constant at 20 min/transect. All butterflies within a 5 m × 5 m visual field in front of the observer were identified and their behavior was recorded. Timers were stopped for capture and recording. Any butterflies that observers were unable to identify in the field were captured using a net and transported to the lab in a glassine envelope for identification. To minimize observer bias, surveyors were rotated in each filter strip throughout the season. Two surveys occurred in 2002 (July 5–22 and July 22–August 15) and 2003 (June 16–July 12 and July 15–August 11).

To better understand the relationship between filter strips and the butterfly community, the butterfly species were separated into two guilds before conducting the analyses—disturbance-tolerant and habitat-sensitive (Table 1). Each species was categorized based upon information presented in Opler and Krizek (1984), Scott (1986), Glassberg (1999) and

Table 1

Numbers of individuals of each butterfly species observed during transect surveys of 49 filter strips during the summers of 2002 and 2003 in southwest Minnesota

Species	Number of individuals	Guild category
<i>Everes comyntas</i> (eastern tailed-blue)	537	Disturbance-tolerant
<i>Danaus plexippus</i> (monarch)	321	Disturbance-tolerant
<i>Colias eurythemelphilodice</i> (orange/clouded sulphurs) ^a	303	Disturbance-tolerant
<i>Ancyloxypha numitor</i> (least skipper)	118	Disturbance-tolerant
<i>Speyeria idalia</i> (regal fritillary)	90	Habitat-sensitive
<i>Vanessa cardui</i> (painted lady)	77	Disturbance-tolerant
<i>Cercyonis pegala</i> (common wood-nymph)	69	Habitat-sensitive
<i>Vanessa atalanta</i> (red admiral)	67	Disturbance-tolerant
<i>Pieris rapae</i> (cabbage white)	25	Disturbance-tolerant
<i>Satyroides eurydice</i> (eyed brown)	17	Habitat-sensitive
<i>Pholisora catullus</i> (common sootywing)	15	Disturbance-tolerant
<i>Anatrytone logan</i> (Delaware skipper)	14	Habitat-sensitive
<i>Papilio polyxenes</i> (black swallowtail)	8	Disturbance-tolerant
<i>Phyciodes tharos</i> (pearl crescent)	6	Disturbance-tolerant
<i>Speyeria cybele</i> (great spangled fritillary)	6	Habitat-sensitive
<i>Pyrgus communis</i> (common checkered-skipper)	5	Habitat-sensitive
<i>Limenitis archippus</i> (viceroys)	4	Disturbance-tolerant
<i>Polites peckius</i> (Peck's skipper)	4	Disturbance-tolerant
<i>Papilio glaucus</i> (eastern tiger swallowtail)	3	N/A ^b
<i>Lycaena hylus</i> (bronze copper)	2	Habitat-sensitive
<i>Polites mystic</i> (long dash)	2	Habitat-sensitive
<i>Polites themistocles</i> (tawny-edged skipper)	2	Disturbance-tolerant
<i>Celastrina argiolus</i> (spring azure)	1	Habitat-sensitive
<i>Epargyreus clarus</i> (silver-spotted skipper)	1	Disturbance-tolerant
<i>Limenitis arthemis asyntax</i> (red-spotted purple)	1	Disturbance-tolerant
<i>Poanes hobomok</i> (Hobomok skipper)	1	N/A ^b
<i>Polites origines</i> (crossline skipper)	1	Habitat-sensitive
<i>Speyeria aphrodite</i> (Aphrodite fritillary)	1	Habitat-sensitive
29 Total species	1701 ^c	

Butterflies occurring commonly in anthropogenically disturbed areas are classified as disturbance-tolerant; species requiring unaltered habitat during any part of their life cycle are classified as habitat-sensitive.

^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 88 individuals not identified to species.

Ries et al. (2001). Disturbance-tolerant butterflies are species that can be found commonly in areas altered by humans such as suburban lawns and gardens. Habitat-sensitive species have more specific requirements for habitat, either due to larval hostplant requirements or the needs of other life stages, and are often found only in relatively natural areas.

A vegetation survey was completed in conjunction with each round of butterfly surveys. Eleven 0.5 m × 0.5 m quadrats were regularly spaced every 20 m for the length of the transect. Estimation of the percentage of cover followed a modification of Daubenmire (1959) method using percentage cover as a continuous variable rather than percentage

classes. At each quadrat, an observer estimated the coverage of all grass, all forbs, bare ground, standing dead vegetation and litter (hereafter all percentage cover estimates will be referred to as coverage). The grass coverage estimate was then further broken down into several component estimates: switchgrass, other natives, non-natives, wheatgrass and quackgrass (*Agropyron*) species and shoots. The coverage of switchgrass was estimated independently of other natives due to its preponderance in seeding plans. The coverage of *Agropyron* species was estimated independently because of the difficulty of distinguishing native species from non-native species in the field. This genus was therefore excluded from analyses

comparing relative coverages of non-native and native grasses.

Vegetation height and vertical density estimation followed a modification of Robel et al. (1970) method. An observer positioned at a distance of 1.5 m from a Robel pole and at a height of 1 m, recorded the maximum height of vegetation (live or dead) in front of the pole, and the minimum height at which visual obstruction of the pole was not complete. This measure provides an index of the vertical density of the vegetation.

Nectar availability in the strips was estimated by counting the numbers of ramets (stems emerging independently from the ground) in bloom in each quadrat. In 2003, the species richness of both forbs and grasses was also tallied for each quadrat. For those filter strips that had trees in them, the number of trees was estimated, as was the distance of the trees from the transect. Adjacent cover types were also recorded.

Width of each filter strip (both sides) was measured using a laser range finder at the beginning, middle and end of the transects, using the mean width value in all analyses. Width measurements were taken from aerial photos for those sites where lack of access or visual obstruction prevented the use of the range finder.

Butterfly abundance and Shannon–Weiner diversity (H') were calculated as means of all rounds, while species richness was tallied across rounds to arrive at a total number of species observed at each site over both years. Regression analyses were used to identify any relationships between filter strip width and butterfly abundance and diversity. The abundances of species with a sufficient sample size (>50 observations) were also used as a response variable in the analyses of width and vegetative composition.

All vegetation coverage data were expressed as proportions, and then transformed by taking the square roots, and then the arcsines. The 11 vegetative variables (coverage of switchgrass, coverage of other native grasses, coverage of non-native grasses, coverage of grass shoots, coverage of forbs, coverage of bare ground, coverage of standing dead vegetation, coverage of litter, number of ramets in bloom, vegetation height and vertical density) were analyzed using principal components analysis (PCA), conducted on the correlation matrix. The first four principal components, which all had eigenvalues greater than one, were rotated using varimax factor

rotation (Cody and Smith, 1997), which allowed for a clearer interpretation of the loadings in the four axes (factors). These four rotated factors were then entered into a series of stepwise regressions (probability to enter = 0.15) to examine what factors might influence total butterfly abundance, diversity and the abundance and diversity of the disturbance-tolerant and habitat-sensitive butterfly guilds.

3. Results

Native species often observed in the filters strips included Canada wild rye (*Elymus canadensis*), Indiangrass (*Sorghastrum nutans*) and big and little bluestem (*Andropogon* spp.). Among the non-native grasses, smooth brome (*Bromus inermis*), reed canarygrass (*Phalaris arundinacea*) and quackgrass (*Agropyron repens*) were often present in filter strips. Common forbs in filter strips included Canada thistle (*Cirsium canadense*), alfalfa (*Medicago sativa*) and sweet clover (*Melilotus* spp.).

The planting type categories, which were determined a priori, contained significant variation in coverage of various vegetation elements. Thus, the categories primarily describe the most dominant vegetation in the strips. For example, the mean coverage of switchgrass among the 14 strips in the switchgrass-dominated treatment was 52%, and the mean coverage of non-native grasses in the 15 non-native strips was 56%. The analysis focused more on vegetation variables than planting type categorization because planting type did not always reflect realized vegetation composition.

Some counties within the study area had a higher prevalence of non-native filter strips, while others had more switchgrass filter strips. Likewise, some areas had more narrow strips and others had wider strips, depending on the availability of additional funding sources in the counties. However, for the strips in this study, filter strip width did not significantly differ among the three planting treatments ($F = 2.70$, $p = 0.08$).

Over the course of the summers of 2002 and 2003, 1789 individual butterflies of 29 species were observed in the filter strips (Table 1) and 1490 individuals of 16 species were observed in the disturbance-tolerant guild; the habitat-sensitive guild

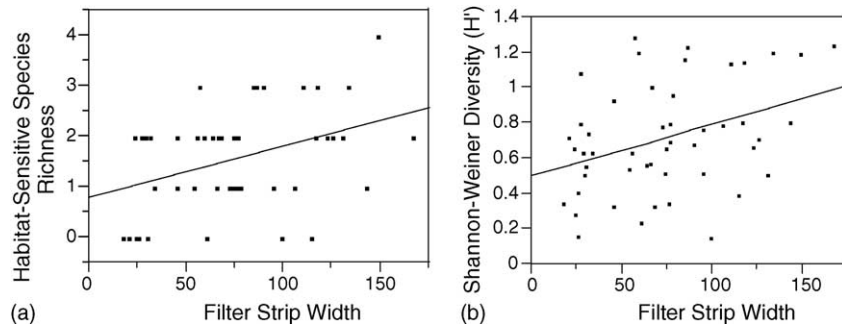


Fig. 1. Linear regressions of filter strip width (m) and response variables of the butterfly community surveyed during the summers of 2002–2003 in southwest Minnesota. Relationship between filter strip width and (a) species richness of habitat-sensitive butterflies (d.f. = 48, $R^2 = 0.15$, $p < 0.01$) and (b) Shannon–Weiner diversity of butterflies (d.f. = 48, $R^2 = 0.14$, $p < 0.01$).

had 207 individuals of 11 species. *Everes comyntas*, the eastern tailed-blue, was the most abundant species, accounting for 30% of the total abundance. The monarch (*Danaus plexippus*) and sulphurs (*Colias* spp.) were the next most abundant species, accounting for 19 and 18% of the total abundance, respectively (Table 1).

The width of filter strips used in the project ranged from 18 to 167 m. The diversity (H') of butterflies in the sampled area was positively correlated with the width of filter strips (Fig. 1b, $R^2 = 0.14$, $p < 0.01$), but butterfly abundance was not ($R^2 = 0.01$, $p = 0.59$). The positive relationship between butterfly diversity and filter strip width was driven by the habitat-sensitive butterflies; abundance of habitat-sensitive butterflies was highly positively correlated with filter strip width ($R^2 = 0.14$, $p < 0.01$). Species richness of habitat-sensitive butterflies was also

positively correlated with strip width (Fig. 1a, $R^2 = 0.15$, $p < 0.01$). By contrast, species richness of disturbance-tolerant butterflies was not correlated with filter strip width ($R^2 = 0.03$, $p = 0.21$). Larger species in the Nymphalidae family were more sensitive to filter strip width than other species. Of the eight species analyzed individually, *D. plexippus*, *S. idalia* and *V. atalanta* were positively correlated with filter strip width (Table 2).

Butterfly abundance and richness as well as the abundance of the eight individual species were examined with respect to the four rotated vegetation factors from the PCA. Butterfly abundance and disturbance-tolerant abundance were best explained by factor 3 (Table 3), a linear combination of forb cover and the number of ramets in bloom (Table 4). Habitat-sensitive species abundance was best explained by factor 1, a combination of the vertical

Table 2

Responses of the eight most abundant species R^2 values from regressions on mean abundances with rotated vegetation factors and width

Species	Factor 1	+/-	Factor 2	+/-	Factor 3	+/-	Factor 4	+/-	Width	+/-
<i>A. numitor</i>	0.0015		0.1657**	–	0.2578***	–	0.0075		0.03	
<i>C. eurytheme</i>	0.0277		0.0392		0.0561		0.0499		0.02	
<i>D. plexippus</i>	0.0147		0.0024		0.0003		0		0.26**	+
<i>E. comyntas</i>	0.0229		0.0089		0.3776***	–	0.0079		0.05	
<i>V. atalanta</i>	0.0015		0.0032		0.0011		0.0112		0.11*	+
<i>V. cardui</i>	0.0070		0.0150		0.0066		0.1215*	–	0.01	
<i>C. pegala</i>	0.0808*	–	0.0004		0.0100		0.0833*	–	0.02	
<i>S. idalia</i>	0.1220*	–	0.0157		0.0017		0.0020		0.15**	+

d.f. = 48. See Table 4 for interpretation of variables.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.0010$.

Table 3

Results of stepwise regressions on abundance and species richness of all butterflies and of the two guilds, disturbance-tolerant (DT) and habitat-sensitive (HS) butterflies

Butterfly variables	d.f.	R ²	Variables in best model	Direction of relationship
Total abundance	48	0.33 ^a	Factor 3	Negative
HS abundance	48	0.12 ^b	Factor 1	Negative
DT abundance	48	0.32 ^a	Factor 3	Negative
Total richness	48	0.05	Factor 3	Negative
HS richness	48	0.07	Factor 1	Negative
DT richness	48	0.07	Factor 3	Negative

^a Indicates significance at the $p < 0.001$ level.

^b Indicates significance at the $p < 0.05$ level.

density and height of the vegetation and percent switchgrass.

The analysis of individual species' abundances with the vegetation factors demonstrated an inconsistent response across families, guilds and sizes (Table 2). The only species that were correlated with factor 1 were two habitat-sensitive species. Abundances of *C. pegala* and *S. idalia*, both larger grassland butterflies, were negatively correlated with factor 1 (Table 2), indicating positive relationships with the height and vertical density of vegetation (Table 4). *A. numitor*, a small, disturbance-tolerant skipper, was the only species found to be correlated with factor 2 (Table 2). This negative relationship represents a positive association with coverage of non-native grasses and a negative correlation with coverage of shoots (Table 4). The abundances of two small, disturbance-tolerant species, *A. numitor* and *E. comyntas*, were negatively correlated

with factor 3 (Table 2), indicating a positive relationship between the abundances of these species and the coverage of forbs and the number of ramets in bloom (Table 4). The abundances of *V. cardui* and *C. pegala* were negatively correlated with factor 4 (Table 2), indicating a negative relationship with standing dead vegetation, and a positive correlation with coverage of native grass (Table 4).

4. Discussion

Abundance and richness of habitat-sensitive butterflies was positively correlated with filter strip width. Thus, species adapted to tallgrass prairie and sensitive to disturbance may not benefit from narrow plantings. The relationship between filter strip width and the butterfly community is more complicated; however, overall butterfly abundance was not correlated with filter strip width. This result was especially unexpected given the large range of widths addressed by this study (18–167 m). To the human eye, a filter strip 18 m wide appears as an insignificant band of grass, while a strip 170 m wide seems a substantial area of habitat in which one might reasonably expect to encounter even large mammalian wildlife. An examination of sensitivity to width also demonstrates that larger brushfoots (Nymphalidae) have higher abundances in wider strips. *D. plexippus*, *S. idalia* and *V. atalanta* are all large butterflies and strong fliers, but they have very different habitat requirements. *S. idalia* is habitat-sensitive and has been shown to be responsive to habitat edges, contrasting sharply with *D. plexippus*, a disturbance-tolerant generalist which is unaffected by grassland-crop edges (Ries and Debinski, 2001).

Table 4

Rotated factor loadings from a principal components analysis of vegetation variables

	Factor 1	Factor 2	Factor 3	Factor 4
Switchgrass (%)	-0.80	0.24	0.34	0.19
Native grass (%)	0.09	0.48	0.19	-0.65
Non-native grass (%)	0.54	-0.74	-0.08	0.04
Shoots (%)	-0.09	0.80	-0.14	0.02
Forbs (%)	0.02	0.33	-0.83	-0.14
Bare ground (%)	0.23	0.72	-0.37	-0.05
Litter (%)	0.45	-0.07	0.06	0.34
Standing dead vegetation (%)	-0.12	0.14	0.20	0.77
Number of ramets in bloom	0.00	0.01	-0.91	0.00
Vertical density	-0.94	-0.11	0.08	0.07
Vegetation height	-0.83	0.01	-0.16	0.11

Loadings that we consider to be the most important to a factor are in bold.

The results highlight the importance of flowering plants to butterflies, and bring into focus an opportunity to improve filter strips as butterfly habitat. The use of forbs as part of the seed mix for filter strips is rare. Approximately 11% of the filter strips identified as potential study sites contained forbs in the planting plan, and half of those list only sweet clover (*Melilotus* spp.). There are several potential reasons for this. Planting native forbs is more expensive than planting just grass. The 2004 online catalog for Ion Exchange, a large Midwestern prairie seed company, charges US\$ 10/lb for a mix of native grasses and US\$ 100/lb for its “butterfly/hummingbird prairie mix” which adds 26 forb species. Thus, the landowner may have to pay a significant premium to have forbs in his/her filter strip. Secondly, invasion of filter strips by Canada thistle (*Cirsium canadense*), a noxious weed, is a widespread problem; the NRCS requires landowners to mow or spray problem areas. For many farmers, the easiest way to control thistles is to spray the filter strip with an herbicide designed to specifically kill broad-leaved plants (it does not affect grasses). This type of treatment obviously kills forbs intentionally planted as well as the thistles. An additional barrier to planting forbs is that the primary function of filter strips is water filtration; creation of butterfly habitat is a secondary benefit.

The positive relationship between abundance of habitat-sensitive species and specifically larger grassland butterflies such as *C. pegala* and *S. idalia*, with the height and vertical density of vegetation also makes sense. These species may need tallgrass to provide habitat structure, and a variety of microhabitat conditions. On hot, sunny midafternoons, many butterflies stay deep in the vegetation, potentially to find shade or moisture.

The analysis of how the eight most abundant species respond to filter strip width and vegetation yielded a wide array of relationships. Given that the overall butterfly community responds positively to forb coverage, the lack of a consistent response to forbs amongst the eight most abundant species was somewhat surprising. The fact that the two species which exhibited a positive relationship with forbs were the two smallest species observed in the transects (*E. comyntas* and *A. numitor*) may help explain these findings; the correlation may be due to higher energy demands in smaller butterflies, which could cause

these butterflies to remain in close proximity to nectar sources. To examine whether the strong relationship with forbs was being driven by the most abundant species in the surveys, *E. comyntas* was removed from the dataset and a new analysis was conducted. Butterfly abundance without *E. comyntas* was positively correlated with coverage of forbs (d.f. = 48, $R^2 = 0.18$, $p = 0.0024$). Thus, although the response was not consistent across all species, the majority of the butterfly community exhibits a positive relationship with coverage of forbs.

This research indicates that even narrow filter strips were used by butterflies. However, wider plantings support a higher diversity of butterflies, as well as larger abundances of habitat-sensitive butterflies. Therefore, increased filter strip width may appeal to managers wishing to provide habitat for species beyond those seen in suburban yards. Increasing the vegetation height and vertical density may also influence the richness of such habitat-sensitive species. Abundances of forbs and the availability of nectar resources may affect a filter strip's ability to support a higher abundance of butterflies overall. Thus, enhancing filter strips by the use of wider plantings consisting of more warm-season grasses (which tend to be taller) and forbs should be accomplished whenever financially possible.

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