Factors affecting butterfly use of filter strips in Southwest Minnesota

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Factors affecting butterfly use of filter strips in Southwest Minnesota

by

Kathleen Fullin Reeder

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

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This is to certify that the master's thesis of

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Signatures have been redacted for privacy
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GENERAL INTRODUCTION

Introduction

White settlement of the Midwestern United States resulted in a dramatic conversion of native prairie to pasture and small grains. Land use in the region then changed again as part of the worldwide trend towards agricultural intensification after World War II. In the Midwest this was manifested as an increase in the acreage of rowcrops such as corn and soybeans, which displaced the small grains and pastureland. The federal government has recognized that agricultural intensification, while boosting productivity, has led to increased soil erosion and loss of wildlife habitat. In 1985, the Conservation Reserve Program (CRP) was created in an effort to re-establish natural areas, including grassland in the Midwest (Heard, 2000). This program reimburses farmers for retiring acres of land from production by replacing crops with perennial vegetation. In 1996, the United States Department of Agriculture (USDA) began Continuous Enrollment CRP as a way of targeting the land most susceptible to erosion (United States Congress, 1996). This extension of the CRP allows farmers who meet eligibility requirements to enroll highly erodible land into conservation practices without having to compete during a limited sign-up period. Continuous Enrollment CRP applies mostly to linear plantings, known as buffers, which are intended to reduce wind and water erosion. Examples of such practices include shelterbelts and living snow fences, grassed waterways, and riparian buffer strips and filter strips. Promoted under the National Conservation Buffer Initiative, the USDA’s goal was to plant two million miles of buffers by 2002. In addition to improving water quality and providing erosion control, the purposes of buffers are to provide aesthetic value and wildlife habitat (Heard, 2000).
In an effort to target regions with specific conservation concerns, the USDA has partnered with states to fund several Conservation Reserve Enhancement Programs (CREPs). Twenty-five states now have one or more of these projects, in which federal and local funds are pooled to address a given conservation problem. The Minnesota River CREP was one of the first in the nation. The goal of this program was to clean up the Minnesota River, making it possible for people to swim and fish in the river. The program has funded the enrollment of 100,000 acres (~40,500 ha) of marginal cropland, of which 30,000 acres (~12,000 ha) were filter strips (Farm Service Agency, 2004).

The large-scale nature of these conservation efforts creates a need to evaluate how to implement federal easement programs in order to maximally achieve their goals. Researchers from many disciplines have begun to address the effectiveness of buffers relative to several objectives. Lee et al. (1999) and Mersie et al. (2003) studied the ability of buffers to remove sediments and toxins, respectively, from overland runoff. Bryan and Best (1994), Best (2000), Henningsen (2003), and Kammin (2003) researched the suitability of various types of buffers as bird habitat. Chapman and Ribic (2002) evaluated buffer use by small mammals. The success of buffers at providing aesthetic benefits to people has also been demonstrated (Sullivan et al., in press). However, the impact of American farm conservation efforts on butterfly communities remains largely unexplored. This dearth of information is remarkable, given the extensive European interest in the effect of agricultural conservation practices on butterflies (Lagerlöf, 1992; Feber et al., 1994; Sparks and Parish, 1995; Dover and Sparks, 2000; Saarinen, 2002).

Here, we evaluate the potential benefits of filter strips to butterflies in southwest Minnesota. Of the buffer practices eligible under Continuous Enrollment CRP and CREP,
filter strips represent the largest acreage (Lowrance et al., 2002). We chose to address filter strips in particular to address how butterflies respond to a practice that uses grasses, a land-cover type that butterflies native to southwest Minnesota are adapted to.

This thesis presents a study of how the width and vegetative composition of filter strips influences the abundance and diversity of butterflies. We evaluate the relative habitat quality of three filter strip planting types for butterflies. We also assess the differing responses to these variables of two guilds of butterflies, disturbance-tolerant and habitat-sensitive (see definitions, Chapter 2, p. 12).

**Thesis Organization**

Chapter Two describes a study of the butterfly community’s use of filter strips in southwest Minnesota. Butterflies were surveyed at 49 filter strips of varying widths and vegetative compositions. Filter strips were divided into three treatment categories based on their seeding plans; non-native mixes, native mixes, or switchgrass (*Panicum virgatum*). The abundance and diversity of butterflies was analyzed with respect to filter strip width, planting type, and the coverage of various elements of the vegetation. Models of butterfly abundance and richness were created based on vegetation variables. The varying responses of butterflies in two guilds - disturbance-tolerant and habitat-sensitive - to these filter strip variables are also addressed. Chapter Two includes a full presentation and discussion of the methods and results of this research. Chapter Two will be submitted for publication to *Agriculture, Ecosystems and Environment*.

Chapter Three is a general conclusion of the research and discusses the implications of linear habitat on the butterfly community in agricultural landscapes. Chapter Three will not be submitted for publication.
There are three authors listed for Chapter Two. Kathleen Reeder is a graduate student in the Ecology and Evolutionary Biology Interdepartmental Graduate Program and was the primary researcher and author. Dr. Diane Debinski and Dr. Brent Danielson are associate professors in the Department of Ecology, Evolution, and Organismal Biology. Dr. Debinski and Dr. Danielson supervised and guided all research and writing for this thesis.
References


FACTORS AFFECTING BUTTERFLY USE OF FILTER STRIPS IN SOUTHWEST MINNESOTA

A paper to be submitted to *Agriculture, Ecosystems and Environment*

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Abstract

The value of agricultural conservation practices for wildlife, especially invertebrates, has not been thoroughly explored. One common practice, designed to reduce sedimentation and nutrient loads caused by runoff into streams, is the planting of filter strips. Filter strips are areas of herbaceous vegetation planted between agricultural fields and streams. In 2002 and 2003, we studied the butterfly community in filter strips of a variety of widths and vegetative compositions. We used transect surveys to quantify butterfly abundance and diversity and measured vegetative variables in conjunction with each butterfly survey round. We found overall butterfly diversity (H') and abundance of habitat-sensitive butterflies to be positively correlated with filter strip width. Using stepwise regression, we found that the best models to explain butterfly abundance and the species richness of disturbance-tolerant butterflies include the coverage of forbs and the number of ramets in bloom in the strips, and indicate positive relationships between forbs and the butterfly community ($R^2 = 0.33$, $R^2 = 0.07$, respectively). The model that best explained richness of habitat-sensitive butterflies includes vegetation height and density, and is expressed as a positive relationship ($R^2 = 0.07$). The planting of forbs in filter strips is rare, but may be useful for providing food
sources to butterflies. More research on demographic parameters such as reproductive success and mortality is needed to assess whether filter strips represent additional habitat for butterflies, or possible sinks.

1. Introduction

1.1. Farm Conservation Practices and Butterflies

Grassland in the Midwestern United States was 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 acres 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. Examples of these linear buffers include: shelterbelts and living snow fences, which are tree and shrub plantings designed to slow wind; grassed waterways, which conduct water off of crop fields; and riparian buffer strips and filter strips which slow and filter runoff from agricultural fields before it enters streams. Riparian forest buffers integrate tree, shrub, and grass plantings; filter strips are areas of perennial herbaceous vegetation, although pre-existing trees are allowed to remain in the plantings. Whereas buffers are being established primarily to improve water quality and to control soil erosion, additional benefits gained from buffers may include enhancing aesthetics and creating wildlife habitat (Heard, 2000). The stated purposes of filter strips in particular are to reduce sediment and contaminant loads in surface runoff as well as to restore or create habitat for wildlife and
beneficial insects (Natural Resources Conservation Service, 2003). Here, we consider the potential benefits of filter strips for butterflies.

There are several reasons why we stress that the effects of filter strips on Lepidopterans should be considered when evaluating the inclusive benefits of this agricultural conservation practice. Ecologically, butterflies are important to plant communities as pollinators and possibly as herbivores. For example, in Iowa, the viability of the butterfly-pollinated herb prairie phlox (*Phlox pilosa*) was discovered to be dependent upon the butterfly community (Hendrix and Kyhl, 2000). Socially, butterflies have a strong appeal. Butterfly watching is an increasingly popular recreational activity (Kaufman, 2004). Many people help monitor the North American monarch (*Danaus plexippus*) population through citizen science programs such as the University of Minnesota's Monarch Larva Monitoring Project (Howard and Davis, 2004) and the University of Kansas's Monarch Watch Program. Often science teachers use these monitoring schemes as educational tools.

1.2. Butterflies as Indicators

Because butterflies are dependent on one (or a few) specific hostplants for development of the larval stage and adults need flowering plants in general for nectar, changes to the plant community affect butterflies. Some species have a multivoltine life cycle which could allow their populations to respond quickly to such changes in habitat quality. The codependence of butterfly and plant communities makes butterflies useful as potential indicators of habitat change and functional integrity (Erhardt, 1985; Kremen, 1992; Brown and Freitas, 2000), especially in grasslands.
1.3. **Other Studies of Butterflies in Strip Cover**

A few recent studies have documented butterflies using linear strips of habitat in agricultural landscapes. Researchers in Britain found that butterfly species richness in shrubby hedgerows is greater than in surrounding pasturelands (Dover and Sparks, 2000). Ries et al. (2001) found a positive response in butterfly abundance and diversity to roadside prairie plantings in Iowa. They report that among species intolerant of habitat disturbance (habitat-sensitive species), richness was doubled for roadsides planted with native species as compared with grassy and weedy roadsides. The abundance of habitat-sensitive species was almost five times higher in prairie plantings than in grassy areas, and the abundance of species capable of tolerating disrupted habitats (disturbance-tolerant species) was also slightly higher in prairie and weedy stretches than in grassy roadsides. However, the mortality rates of butterflies using roadside plantings were high because of passing vehicles, especially in patches adjacent to paved roads (Ries et al., 2001). Grass filter strips have the potential to provide a similar positive influence on some butterfly species by providing habitat in agricultural environments dominated by rowcrops, without the mortality risk of roadside habitat.

1.4. **Filter Strip Width**

Research on optimum filter strip width for maximizing water filtration has shown that increasing width enhances filtration. Lee et al. (1999) found that doubling the width of a filter strip from 3 m to 6 m increases sediment removal of incoming runoff from 66% to 77%. Schmitt et al. (1999) report that doubling filter strip width from 7.5 m to 15 m increases infiltration and dilution of runoff, although it does not enhance sediment settling. Program rules allow average filter strip width to be anywhere from 33 ft. - 120 ft. (10 m - 37
m) on one side of a waterway, but if additional cost-share programs are available locally, landowners may be reimbursed for establishment of strips wider than 120 feet (37 m). The filter strips in our study are planted on both sides of streams and range from 18 m – 167 m in total width. The high prevalence of wide filter strips in our study area may be because prices for corn and soybeans are low enough that landowners find it economically beneficial to opt for the full width allowable under the program rules.

1.5. Diversity of Plantings

Much of the research currently guiding planting mix formulation evaluates filter strip performance relative to slowing and reducing the sediment and nutrient load of surface runoff. For example, Lee et al. (1999) found switchgrass (*Panicum virgatum*) to be more efficient at removing nutrients and sediments than a mixture of cool season grasses consisting of bromegrass (*Bromus inermis*), timothy (*Phleum pratense*), and fescue (*Festuca spp.*). However, Mersie et al. (2003) report that tall fescue (*Festuca arundinacea*) was more effective than switchgrass at removing an insecticide when the flow rate of the runoff is slow. Managers can use this information to make planting recommendations that fit the specific filtration objectives of the project.

Although the creation of habitat is an objective of filter strips, the potential to integrate both water quality and wildlife habitat priorities when developing planting mixtures has not been fully explored. However, European researchers have examined butterfly response to similar conservation efforts in field boundaries and hedgerows. For example, Sparks and Parish (1995) report that abundance of larval foodplants and floral richness of field boundaries are important factors for many butterfly species in Britain. Smith et al. (1994) demonstrate that sowing a mixture of grasses and forbs into boundary strips in Britain
positively affected butterfly abundance and species richness. In Sweden, Lagerlög et al. (1992) found that field margins with flowering plants benefit pollinating insects. In the Midwest, a wide range of species is used in filter strip planting mixtures, including monocultures of switchgrass, mixes of non-native or native grasses, and mixes of native grasses plus forbs. The work of European researchers indicates that if nectar resources or larval hostplant availability are limiting to butterfly populations in intensely cultivated lands, planting a diverse mixture of native grasses and forbs in filter strips could be of great conservation importance. To our knowledge, this is the first study conducted in the USA to address how the composition and structure of the vegetation in buffer easements on farms affect butterfly abundance and richness.

1.6. Movement Corridors

In addition to providing extra habitat, another potential benefit of filter strips to butterflies is that the strips may serve as dispersal corridors. There is evidence of butterflies using corridors in other ecosystems. Butterflies in Haddad’s (1999) forest clearings experiment moved between patches connected by corridors more often than between unconnected patches. Also, Dover (1990) found that Pierid butterflies use margins of agricultural fields in Britain as flight corridors. If butterflies use strip-cover habitats as movement corridors, then linear grass plantings may act as "stepping stones" between isolated fragments of prairie habitat. In fragmented habitats such as the Midwestern tallgrass prairie, the butterfly community’s role in providing pollination services between disjunct populations of native plant species could be diminished. Reduction in pollination caused by fragmentation has been shown to result in decreased seed set in a butterfly-pollinated herb (Jennersten, 1988), and genetic erosion of herkogamous (plants with spatial separation of
male and female reproductive parts) plant populations in general (Lennartsson, 2002). Linear dispersal corridors such as filter strips could decrease the isolation of fragments by reducing the distance between patches (Noss and Harris, 1986; Ries et al., 2001), and therefore could have important implications for butterfly-pollinated plants as well as butterfly species.

1.7. Risks of Linear Habitat

However, the potential risks of linear habitat formations need study before buffers are promoted as beneficial to butterflies. 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. Predators of butterfly larvae include birds, spiders, and insects (Scott, 1986). Dragonflies and birds prey on adult butterflies, and insects such as wasps and flies parasitize caterpillars. 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 above-ground 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). Thus, the concentration of predators into linear habitats adjacent to crop fields may have a negative impact on survival of butterflies using filter strips. Comparing mortality rates in block-shaped vs. linear habitat is one important way of determining whether filter
strips are possible sink habitats. Information on differences in reproduction between block and strip cover would complete the picture, but will not be addressed here due to the challenge of obtaining such data. Assessing mortality is an important first step, as mortality can be more important than reproduction in regulating population changes (Pulliam and Danielson, 1991).

1.8. Objectives

Our research examines butterfly community composition in a variety of different filter strip widths and plant compositions. Our objectives were to (1) quantify the abundance and diversity of butterflies in filter strips, (2) assess the influence of filter strip width and vegetative composition on butterfly abundance and diversity, and (3) determine whether predation on adult butterflies by aerial predators is higher in filter strips than in block-shaped habitat.

To better understand the relationship between filter strips and the butterfly community, we separated the butterfly species into two guilds before conducting our 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), and 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. Due to the uneven richnesses and abundances of these guilds, we will not compare diversity between guilds; we will use species richness, a component of diversity. By separating the butterfly community into two guilds a priori, we are able to examine how
species of potential conservation interest respond to various filter strip characteristics; these effects may otherwise have been swamped by the abundance of less sensitive species in the community.

2. Methods

2.1. Study Area

We focused our research on filter strips in a five-county area in southwest Minnesota. The study area includes 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; the average number of acres planted to corn and soybeans in these five counties for 2001-2002 was 1,609,250 (~651,000 ha, Minnesota Agricultural Statistics Service, 2003). 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).

We categorized filter strips into three general planting types based on the seeding plans filed with the NRCS: non-native, switchgrass-dominated, and diverse mixtures of native species. Fourteen non-native, 14 switchgrass, and 15 native strips were selected for use. Six additional strips for which the seeding plans could not be located were included in the research but were excluded from analyses based on planting type treatments. We surveyed 49 filter strips, 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.

To reduce the number of confounding variables, we selected filter strips with either no trees or minimal numbers of trees growing in them. Tree plantings are not a part of the
filter strip conservation practice, but if trees are already growing along a stream they are sometimes present in filter strips. We counted all trees present in the strips within 100 m of the transect, and filter strips were placed into the following categories: 0 trees (30 strips), 1-10 trees (16 strips), or 11-50 trees (3 strips). A one-way analysis of variance (ANOVA) found no differences in either the abundance ($F = 0.41$, $p = 0.66$) of butterflies among these three categories, or butterfly richness ($F = 1.17$, $p = 0.32$) among the three categories, indicating that the potentially confounding effects that trees could present were non-existent in our study.

2.2. Butterfly Surveys

Each site had one transect, and each transect, marked with pin flags, was 200 x 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 (≥18 degrees Celsius), sunny (<60% cloud cover), and calm (sustained winds < 16 km/h) days between 0900-1730 h. Butterfly survey methods followed a modification of Thomas (1983). Transects were walked at a speed of 10 meters per one minute; survey effort was constant at 20 minutes per transect. All butterflies within a 5 x 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 we rotated surveyors in each filter strip throughout the season. In 2002, we conducted our two survey rounds from 7/5/02 to 7/22/02, and from 7/22/02 to 8/15/02. In 2003, we conducted the two survey rounds from 6/16/03 to 7/12/03, and from 7/15/03 to 8/11/03.
2.3. *Vegetation Sampling*

A vegetation survey was completed in conjunction with each round of butterfly surveys. Eleven 0.5 m x 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’s (1959) method. However, we recorded percentage cover as a continuous variable rather than using Daubenmire’s (1959) 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 because, due to its preponderance in seeding plans, it is one of three planting treatments in this study. 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.’s (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 richnesses of both forbs and grasses were also tallied for each quadrat. For those
filter strips that had trees in them, the numbers of trees were estimated, as were the distances of the trees from the transect. Adjacent cover types were also recorded.

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

2.4. Adult Predation Experiment

To address whether predation on adults was higher in filter strips than in block-shaped CRP fields, three pairs of sites were chosen. Each pair of sites included one filter strip and one CRP field of similar vegetative composition, located within 3 km of each other. The three selected CRP fields were between 2 - 5 acres (0.81 – 2.02 ha) large, the three filter strips ranged from 1.75 – 20 acres (0.71 – 8.09 ha). All selected CRP fields are bordered on at least three sides by rowcrops, and the fourth side was either road or crops. Two pairs of sites were switchgrass-dominated, and one pair consisted of native grass mixes. At each site, five live, adult *Colias eurytheme* butterflies were tethered with approximately 25 cm of thread, tied around the junction of the abdomen and the thorax, then attached to a stem of grass or forb. After 24 h, the butterflies were checked for signs of attack by aerial predators. We conducted 24-h experiments on each pair of sites 3 separate times, with a total of 45 butterflies in the blocks and 45 in the strips.

2.5. Data Analysis

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 seen at each site over both years. The response variables presented here are raw, as transformations did not significantly improve the normality of their distributions.

Regression analyses were used to identify any relationships between filter strip width and butterfly abundance and diversity. The relationships between filter strip planting type and butterfly abundance and diversity were analyzed using one-way ANOVAs.

All vegetation coverage data were expressed as proportions, 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, # of ramets in bloom, vegetation height and vertical density) were subjected to a 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.

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.

We conducted a Student’s t-test to determine whether the risk of predation of adult butterflies differed between filter strips and block-shaped habitat.
3. Results

3.1 General Vegetation Observations

Native species we often observed in the filters strips include 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% (Fig. 1).

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 our study, filter strip width did not significantly differ among the three planting treatments ($F = 0.13$, $p = 0.08$).

3.2 General Butterfly Observations

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

3.3. Filter Strip Width

The width of filter strips used in the project ranged from 18 – 167 m. The diversity (*H'*') of butterflies in the sampled area was positively correlated with the width of filter strips (Fig. 2, *R*^2^ = 0.14, *p* < 0.01), but butterfly abundance was not (Fig. 3, *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. 4, *R*^2^ = 0.15, *p* < 0.01). By contrast, species richness of disturbance-tolerant butterflies was not correlated with filter strip width (Fig. 5, *R*^2^ = 0.03, *p* = 0.21).

Larger species in the Nymphalidae family appeared to be 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).

3.4. Planting Treatments

Overall butterfly abundance had no significant relationship with planting type (*F* = 1.39, *p* = 0.26), but the habitat-sensitive butterfly guild displayed a different pattern than the disturbance-tolerant butterflies. The abundance of habitat-sensitive butterflies was lower in the non-native planting type than in native grass filter strips (Fig. 6, *F* = 3.46, *p* < 0.05).

Similarly, butterfly diversity (*H'*') was lower in the non-native planting type than in filter strips planted to a native mix (*F* = 3.55, *p* < 0.05). This was also driven by the response
of habitat-sensitive butterflies; the species richness of disturbance-tolerant butterflies was not significantly different among the three treatments (Fig. 7, F = 1.05, p = 0.36), while the species richness of habitat-sensitive species did differ among treatments. (Fig. 8, F = 3.25, p < 0.05).

3.5. Vegetation Models

The model that best explained butterfly abundance included factor three (Table 3), which was primarily a negative, linear combination of forb cover and the number of ramets in bloom (Table 4). Butterfly abundance was negatively correlated with factor three, indicating a positive relationship between forbs and butterfly abundance.

The best species richness model also included just factor 3 (Table 3). This was a negative relationship, indicating a positive relationship between butterfly species richness and forbs (Table 4). We also conducted separate analyses for disturbance-tolerant and habitat-sensitive species. The best model for species richness of disturbance-tolerant species also included factor three (Table 3). This was, again, a negative relationship, signifying a positive relationship between species richness of disturbance-tolerant butterflies and forbs (Table 4). The species richness of habitat-sensitive species was best explained by factor one (Table 3). Species richness of habitat-sensitive butterflies was negatively correlated with factor one, a negative, linear combination of the height and vertical density of vegetation (Table 4). This represents a positive relationship between richness of habitat-sensitive butterflies and vegetation height and vertical density.

3.6. Individual Species Responses to Vegetation Factors

The abundances of the eight species with a sufficient sample size (<50 individuals) were examined with respect to the four rotated vegetation factors from the PCA. The
analysis of individual species' abundances with the vegetation factors demonstrated an inconsistent response across families, guilds, and sizes (Table 4). The only species that were correlated with factor one were two habitat-sensitive species. Abundances of *C. pegala* and *S. idalia*, both larger grassland butterflies, were negatively correlated with factor one (Table 2). This reflects 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 two (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 the factor three (Table 2). This represents 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 four (Table 2). This represents a negative relationship with standing dead vegetation, and a positive correlation with coverage of native grass (Table 4).

3.7. Predation Experiment

We found no significant differences in predation rates between the linear and block-shaped habitats. Of the 45 opportunities for predation in each habitat shape, there were 11 attacks by predators in the block-shaped habitats and 12 attacks in the filter strips. Our observations indicated that many of these attacks were perpetrated by arthropods, including ground-dwelling taxa such as ants and spiders.
4. Discussion

4.1. Filter Strip Width

Abundance and richness of habitat-sensitive butterflies is positively correlated with filter strip width. 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 is 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. From the perspective of butterfly populations, however, this range of habitat widths appears not to be broad enough to cover thresholds governing abundance. This is heartening news to landowners and managers who may not have sufficient resources to plant the widest filter strips.

An examination of sensitivity to width 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 edges (Ries and Debinski, 2001). Perhaps these species’ sensitivity to width arises from their large body size. Theoretical work predicts that, among birds and mammals, home range sizes of larger species will be more heavily affected by habitat fragmentation.
This type of work has not been conducted on butterflies to our knowledge, but similar processes may be at work.

4.2. Planting Type

The effect of filter strip planting type on butterfly abundance is seen among the habitat-sensitive butterflies, which have lower numbers in non-native grass mixes than in native mixes. These analyses apparently demonstrate that any of the three planting types examined in this research will provide habitat for butterflies, but that the non-native strips do not satisfy the demands of all species, especially not the habitat-sensitive species. Findings based on planting type alone are limited, however, since the categories are based on a priori planting plans rather than on the realized vegetative composition. Analyses based upon the percentage of cover of vegetative components give a more accurate picture. An example of this discrepancy is that the analysis based on planting type suggests that numbers of habitat-sensitive butterfly species and individuals are lower in non-native strips than in native mixes, but linear regressions between abundance and richness of habitat-sensitive butterflies and the realized percentage of cover of non-native grass show no significant correlations. We conclude that, although recommendations based on simple categorizations of planting type would be convenient for managers, they lack the accuracy of inferences based on the vegetation model. This is due to the fact that the vegetative composition of filter strips planted with the same mix can develop quite differently depending on management, levels of invasion by weedy species, soil type, and a myriad of other factors.

4.3. Vegetation Models

The importance of a forb component in filter strip vegetation is clearly demonstrated by this research. Many grassland butterflies depend upon nectar for energy during their adult
phase. Although we did not collect data on the spatial locations of butterflies relative to various plant species, our experience suggests that butterflies were much more abundant in portions of transects that had a large abundance of forbs in bloom.

Additionally, most species of grassland butterflies use forbs for larval hostplants (except several skipper species which use grasses). The grassland butterfly community uses a diverse array of plant species as hostplants, and some butterfly species are limited to one or two species of hostplant. This suggests that a high diversity of native plants in filter strips would provide resources to the larval stages of more butterfly species.

Our results underline 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 that we identified as potential study sites contain forbs in the planting plan, and half of those list only sweet clover (*Melilotos* spp.). There are several potential reasons for this. Primarily, planting native forbs is more expensive than planting just grass. The 2004 online catalog for Ion Exchange, a large Midwestern prairie seed company, charges $10/lb for a mix of native grasses, and $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. There has not been much research on the efficiency of various forb mixes at filtering or slowing runoff. Such information would inform agency personnel or landowners wishing to make a wise planting choice and provide documentation that there is, or is not, a cost of decreased filtration with additional forbs.

The vegetation models also highlight that vegetation structure important for habitat-sensitive butterflies. The fact that vegetation height and vertical density are positively correlated with the richness of habitat-sensitive butterflies makes sense in light of the fact that most of the species belonging to the habitat-sensitive guild are adapted to the tallgrass prairie biome. These species may need tall grass 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. Disturbance-tolerant species may be adapted to the short grass more typical of disturbed areas, but habitat-sensitive species benefit from the added structure which tall grass provides.

4.4. Individual Species Responses to Vegetation Factors

The analysis of how the eight most abundant species respond to filter strip width and vegetation yields a wide array of relationships. This variety is better understood in light of the fact that these eight species are not similar in any attribute other than frequency in strips; four families, both habitat guilds, and a wide range of body sizes are represented in this group. 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 is somewhat surprising. The fact that the two species which exhibited a positive relationship with forbs are the two smallest species observed in the transects (E. comyntas and A. numitor) may help
explain our 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 *E. comyntas*, the most abundant species in our surveys (Table 1), we removed *E. comyntas* from the dataset and ran a new analysis. Butterfly abundance without *E. comyntas* is positively correlated with coverage of forbs (df = 48, $R^2 = 0.18$, $p = 0.0024$). Thus, although the response is not consistent across all species, the butterfly community overall exhibits a positive relationship with coverage of forbs.

4.5. *Predation Experiment*

We were unable to detect a difference in predation rates on adult butterflies between the two landscape types; one potential reason that is that we encountered a different suite of predators than we expected. The pilot experiment was intended to measure predation rates by aerial predators such as birds and dragonflies, but most of the predation that we observed was from spiders or insects such as wasps and ants. The predators that did attack the butterflies may perceive the landscape on a different scale than birds or larger flying insects, so the configuration of the habitat may not influence their rates of predation upon butterflies. More work needs to be done to address mortality risks to butterflies in filter strips, including predation rates on eggs, larvae, and pupae, to provide a full picture of the habitat value of filter strips to butterflies.

4.6. *Management Implications*

Our research indicates that even narrow filter strips are 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 that which we may see in our suburban yards. Increasing the vegetation height and vertical density may also influence the richness of such habitat-sensitive species. Abundance of forbs and the availability of nectar resources may affect a filter strip’s ability to support a higher abundance of butterflies overall. We recommend enhancing filter strips by the use of wider plantings consisting of more warm-season grasses (which tend to be taller) and forbs whenever financially possible. These recommendations come with a caveat, however. There is not enough information on butterfly reproduction or mortality in strip-cover habitat to justify an assertion that filter strips provide quality habitat. Clausen et al. (2001) found that butterfly species and individuals were more numerous in non-linear, block-shaped habitats than in linear habitats in an agroecosystem in Denmark. Possibly, the filter strips in our study are populated from nearby non-linear habitats such as CRP fields rather than operating as self-sustaining systems. More work is needed on these questions to ensure that we are not unintentionally attracting butterflies into linear habitats which may represent sinks or ecological traps.
Acknowledgements

Funding for this project was provided by the Natural Resources Conservation Service – Wildlife Habitat Management Institute. We are indebted to William Hohman and Kirk Moloney for comments on this manuscript. Tony Thompson of the Willow Lake Farm welcomed research on his filter strips as well as researchers living on his property. This research was made possible by the gracious cooperation of many local landowners and operators. We thank Mark Oja of the USDA-NRCS MN State Office for supporting the establishment of this research. We are grateful for the cooperation of the NRCS district conservationists and the Cottonwood County Soil and Water District. Stephanie Hacker and Brooke Arp provided excellent field assistance, and Gordon Reeder assisted with all portions of the project.
References


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. 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; species requiring unaltered habitat during any part of their life cycle are classified as habitat-sensitive.

<table>
<thead>
<tr>
<th>Species</th>
<th># of Individuals</th>
<th>Guild Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Everes comyntas</em> (Eastern tailed-blue)</td>
<td>537</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Danaus plexippus</em> (Monarch)</td>
<td>321</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Colias eurytheme/philodice</em> (Orange/Clouded sulphurs)*</td>
<td>303</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Ancyloxypha numitor</em> (Least skipper)</td>
<td>118</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Speyeria idalia</em> (Regal fritillary)</td>
<td>90</td>
<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Vanessa cardui</em> (Painted lady)</td>
<td>77</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Cercyonis pegala</em> (Common wood-nymph)</td>
<td>69</td>
<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Vanessa atalanta</em> (Red admiral)</td>
<td>67</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Pieris rapae</em> (Cabbage white)</td>
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<tr>
<td><em>Satyrodex eurydice</em> (Eyed brown)</td>
<td>17</td>
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</tr>
<tr>
<td><em>Pholisora catullus</em> (Common sootywing)</td>
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<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Anatrytone logan</em> (Delaware skipper)</td>
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<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Papilio polyxenes</em> (Black swallowtail)</td>
<td>8</td>
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</tr>
<tr>
<td><em>Phyciodes tharos</em> (Pearl crescent)</td>
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<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Speyeria cybele</em> (Great spangled fritillary)</td>
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</tr>
<tr>
<td><em>Pyrgus communis</em> (Common checkered-skipper)</td>
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<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Limenitis archipus</em> (Viceroy)</td>
<td>4</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Polites peckius</em> (Peck’s skipper)</td>
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</tr>
<tr>
<td><em>Papilio glaucus</em> (Eastern tiger swallowtail)</td>
<td>3</td>
<td>N/A*</td>
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<tr>
<td><em>Lycaena hyllus</em> (Bronze copper)</td>
<td>2</td>
<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Polites mystic</em> (Long dash)</td>
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<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Polites themistocles</em> (Tawny-edged skipper)</td>
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<td>Disturbance-tolerant</td>
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<td><em>Celastrina argiolus</em> (Spring azure)</td>
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<td>Habitat-sensitive</td>
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<tr>
<td><em>Epargyreus clarus</em> (Silver-spotted skipper)</td>
<td>1</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Limenitis arthemis asyntax</em> (Red-spotted purple)</td>
<td>1</td>
<td>Disturbance-tolerant</td>
</tr>
<tr>
<td><em>Poanes hobomok</em> (Hobomok skipper)</td>
<td>1</td>
<td>N/A*</td>
</tr>
<tr>
<td><em>Polites origines</em> (Crossline skipper)</td>
<td>1</td>
<td>Habitat-sensitive</td>
</tr>
<tr>
<td><em>Speyeria aphrodite</em> (Aphrodite fritillary)</td>
<td>1</td>
<td>Habitat-sensitive</td>
</tr>
<tr>
<td>29 Total Species</td>
<td>1701</td>
<td></td>
</tr>
</tbody>
</table>

* Colias spp. were combined due to initial identification uncertainty
* Species adapted to woody habitats were not classified as disturbance-tolerant or habitat-sensitive
* Does not include 88 individuals not identified to species
Table 2. Responses of the eight most abundant species – $R^2$ values from regressions on mean abundances with rotated vegetation factors and width. $df = 48$. * indicates significance at 0.05 level, ** indicates significance at the 0.01 level, *** indicates significance at the 0.001 level

Factor 1: (-) Vegetation Height, (-) Vertical Density, (-) % Cover Switchgrass

Factor 2: % Cover Shoots, % Cover Bare Ground, (-) % Cover Non-native Grasses

Factor 3: (-) # Ramets in Bloom, (-) % Cover Forbs

Factor 4: % Cover Standing Dead Vegetation, (-) % Cover Other Native Grasses

<table>
<thead>
<tr>
<th>Species</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A.\ numitor$</td>
<td>0.0015</td>
<td>0.1657**</td>
<td>0.2578***</td>
<td>0.0075</td>
<td>0.03</td>
</tr>
<tr>
<td>$C.\ eurytheme$</td>
<td>0.0277</td>
<td>0.0392</td>
<td>0.0561</td>
<td>0.0499</td>
<td>0.02</td>
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<tr>
<td>$D.\ plexippus$</td>
<td>0.0147</td>
<td>0.0024</td>
<td>0.0003</td>
<td>0</td>
<td>0.26**</td>
</tr>
<tr>
<td>$E.\ comyntas$</td>
<td>0.0229</td>
<td>0.0089</td>
<td>0.3776***</td>
<td>0.0079</td>
<td>0.05</td>
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<tr>
<td>$V.\ atalanta$</td>
<td>0.0015</td>
<td>0.0032</td>
<td>0.0011</td>
<td>0.0112</td>
<td>0.11*</td>
</tr>
<tr>
<td>$V.\ cardui$</td>
<td>0.0070</td>
<td>0.0150</td>
<td>0.0066</td>
<td>0.1215*</td>
<td>-</td>
</tr>
<tr>
<td>$C.\ pegala$</td>
<td>0.0808*</td>
<td>-</td>
<td>0.0100</td>
<td>0.0833*</td>
<td>-</td>
</tr>
<tr>
<td>$S.\ idalia$</td>
<td>0.1220*</td>
<td>-</td>
<td>0.0157</td>
<td>0.0020</td>
<td>0.15**</td>
</tr>
</tbody>
</table>
Table 3. Results of stepwise regressions on abundance and species richness of all butterflies and of the two guilds, disturbance-tolerant (D.T.) and habitat-sensitive (H.S.) butterflies. * indicates significance at the p < 0.05 level, ** indicates significance at the p < 0.001 level

<table>
<thead>
<tr>
<th>Butterfly Variables</th>
<th>df</th>
<th>R²</th>
<th>Variables in Best Model</th>
<th>Direction of Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Abundance</td>
<td>48</td>
<td>0.33**</td>
<td>Factor 3</td>
<td>Negative</td>
</tr>
<tr>
<td>H.S. Abundance</td>
<td>48</td>
<td>0.12*</td>
<td>Factor 1</td>
<td>Negative</td>
</tr>
<tr>
<td>D.T. Abundance</td>
<td>48</td>
<td>0.32**</td>
<td>Factor 3</td>
<td>Negative</td>
</tr>
<tr>
<td>Total Richness</td>
<td>48</td>
<td>0.05</td>
<td>Factor 3</td>
<td>Negative</td>
</tr>
<tr>
<td>H.S. Richness</td>
<td>48</td>
<td>0.07</td>
<td>Factor 1</td>
<td>Negative</td>
</tr>
<tr>
<td>D.T. Richness</td>
<td>48</td>
<td>0.07</td>
<td>Factor 3</td>
<td>Negative</td>
</tr>
</tbody>
</table>
Table 4. Rotated factor loadings from a principal components analysis of vegetation variables. Loadings that we consider to be the most important to a factor are in bold.

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Switchgrass</td>
<td>-0.80</td>
<td>0.24</td>
<td>0.34</td>
<td>0.19</td>
</tr>
<tr>
<td>% Native grass</td>
<td>0.09</td>
<td>0.48</td>
<td>0.19</td>
<td>-0.65</td>
</tr>
<tr>
<td>% Non-native grass</td>
<td>0.54</td>
<td>-0.74</td>
<td>-0.08</td>
<td>0.04</td>
</tr>
<tr>
<td>% Shoots</td>
<td>-0.09</td>
<td>0.80</td>
<td>-0.14</td>
<td>0.02</td>
</tr>
<tr>
<td>% Forbs</td>
<td>0.02</td>
<td>0.33</td>
<td>-0.83</td>
<td>-0.14</td>
</tr>
<tr>
<td>% Bare Ground</td>
<td>0.23</td>
<td>0.72</td>
<td>-0.37</td>
<td>-0.05</td>
</tr>
<tr>
<td>% Litter</td>
<td>0.45</td>
<td>-0.07</td>
<td>0.06</td>
<td>0.34</td>
</tr>
<tr>
<td>% Standing Dead Vegetation</td>
<td>-0.12</td>
<td>0.14</td>
<td>0.20</td>
<td>0.77</td>
</tr>
<tr>
<td># Ramets in Bloom</td>
<td>0.00</td>
<td>0.01</td>
<td>-0.91</td>
<td>0.00</td>
</tr>
<tr>
<td>Vertical Density</td>
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<td>-0.11</td>
<td>0.08</td>
<td>0.07</td>
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<tr>
<td>Vegetation Height</td>
<td>-0.83</td>
<td>0.01</td>
<td>-0.16</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Figure 1. Coverage of various elements of the vegetation for the three filter strip planting type categories (based on the seeding plans). Vegetation surveys were conducted during the summers of 2002-2003 in southwest Minnesota.
Figure 2. Linear regression of filter strip width and Shannon-Weiner diversity of butterflies surveyed during the summers of 2002-2003 in southwest Minnesota (df = 48, $R^2 = 0.14$, $p < 0.01$)
Figure 3. Linear regression of filter strip width and abundance of butterflies surveyed during the summers of 2002-2003 in southwest Minnesota (df = 48, $R^2 = 0.01$, p = 0.59)
Figure 4. Linear regression of filter strip width and species richness of habitat-sensitive butterflies, surveyed during the summers of 2002-2003 in southwest Minnesota (df = 48, $R^2 = 0.15$, $p < 0.01$)
Figure 5. Linear regression of filter strip width and species richness of disturbance-tolerant butterflies, surveyed during the summers of 2002-2003 in southwest Minnesota. (df = 48, $R^2 = 0.03$, $p = 0.21$)
Figure 6. ANOVA on the abundance of habitat-sensitive butterflies in three filter strip planting types surveyed in the summers of 2002 and 2003 in southwest Minnesota. Tukey-Kramer pairwise comparisons are indicated by letters above plots. Box ends represent the 25th and 75th quantiles and the line across the box represents the median value (df = 42, F = 3.46, p < 0.05)
Figure 7. ANOVA on species richness of disturbance-tolerant butterflies in three filter strip planting types surveyed during the summers of 2002-2003 in southwest Minnesota. Box ends represent the 25th and 75th quantiles and the line across the box represents the median value (df = 42, F = 1.05, p = 0.36)
Figure 8. ANOVA on species richness of habitat-sensitive butterflies in three filter strip planting types surveyed during the summers of 2002-2003 in southwest Minnesota. Although the ANOVA indicates a significant difference among treatments, Tukey-Kramer pairwise comparisons (indicated with letters above plots) do not. Box ends represent the 25th and 75th quantiles and the line across the box represents the median value (df = 42, F = 3.25, p < 0.05)
GENERAL CONCLUSIONS

Our general findings are consistent with those of other researchers who have found that butterflies use conservation plantings along margins of agricultural fields (Lagerlöff, 1992; Smith et al., 1994; Sparks and Parish, 1995). Our results are also in keeping with other studies that demonstrate the importance of nectar and hostplant availability to butterflies in cultivated habitats (Feber et al., 1994; Sparks and Parish, 1995; Clausen et al., 2001).

Butterflies are using filter strip plantings, regardless of width or planting composition. There is considerable variation in the responses of individual butterfly species to vegetative factors; butterflies do not exhibit unified, community-wide relationships with the habitat variables we examined. However, some general principles have emerged from this investigation. Increasing width and using tall grasses in plantings may lead to a more positive response from butterflies native to tallgrass prairie. Modifying plantings to incorporate more forbs may provide nectar resources to a broader array of species and a greater abundance of butterflies.

In the highly fragmented tallgrass prairie biome in the Midwestern U.S., filter strips have the potential to serve as stepping stones for butterflies between isolated prairie remnants. Our research indicates that butterflies do indeed make use of these linear habitats. More research is needed to understand how the use of filter strips influences butterfly movement across the agricultural landscape. Also, potential risks of filter strips to butterflies warrants further investigation. Observing large numbers of individuals in a habitat type may not be a good indicator of the habitat quality of filter strips without corresponding information about reproductive success and survival.
We recommend that managers who wish to increase the value of filter strips for butterflies, especially those that are more sensitive to disturbance, make them as wide as possible and include warm-season grasses and forbs in the planting mixture. These recommendations are in keeping with the wider movement of prairie restorations in general.
References


