Butterfly response to floral resources at a heterogeneous prairie biofuel production site

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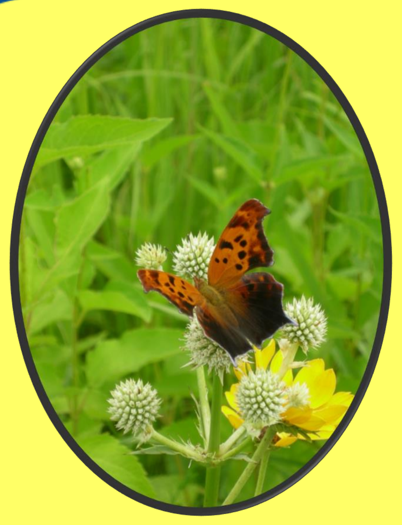

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ABSTRACT

In the Midwestern USA, current biofuel production systems rely on high input monoculture crops that do little to support biodiversity or protect soil and water resources. The University of Northern Iowa's Tallgrass Prairie Center is investigating the feasibility of cultivating and harvesting diverse mixes of native prairie vegetation as a sustainable biofuel. In 2009, we established 48 research plots seeded with one of four treatments: 1) switchgrass monoculture, 2) warm-season grass mix (5 species), 3) biomass mix (16 species of grasses and forbs), or 4) prairie mix (32 species of grasses and forbs). We hypothesized that more diverse plant communities would support a greater abundance and diversity of butterflies. In 2010, just the second growing season after seeding, butterflies were six times more abundant and twice as species rich in biomass and prairie mix plots compared to warm-season grass and switchgrass plots. Our results suggest that implementation of biomass production using diverse mixes of native prairie vegetation on marginal lands could have positive effects on the maintenance of biodiversity in agricultural landscapes

BACKGROUND

The destruction, degradation, and fragmentation of grassland habitats has triggered significant butterfly population declines and range contractions throughout North America (Forister et al., 2010; Swengel et al., 2010). In the Midwestern USA, the conversion of the native tallgrass prairie ecosystem to row crop agriculture over the past 150 years has been described as one of the most rapid and complete ecological transformations in human history (Sampson and Knopf 1994). Poor habitat conditions for butterflies are likely to persist in the region into the future in the absence of significant changes to current agricultural practices. However, numerous authors have suggested that cultivating low-input high-diversity grassland biomass could have both significant energetic and environmental advantages over corn-based ethanol (Hill, 2009; Tilman et al., 2006).

Here we present the results of a study of butterfly and plant communities during early establishment of a heterogeneous prairie biomass production site in Iowa, USA. We chose to study butterflies because they respond rapidly to environmental change and were likely to colonize the site during early establishment; they respond to plant diversity due to their requirements for larval host plants and adult nectar sources; and they serve as indicators of ecosystem health (Scott, 1986). Our specific objectives were: 1) to describe butterfly colonization and use of the site during early establishment, 2) to test the hypothesis that more diverse mixes of native vegetation support more abundant and species rich butterfly assemblages, and 3) to explore relationships between habitat characteristics and butterfly abundance and species richness in plots managed specifically for biomass production.

METHODS

Project Site. Our study was conducted in the Cedar River Natural Resource Area in Black Hawk County, Iowa. The site had a 20-yr history of row crop (corn and soybeans) production until 2009, when our research plots were seeded with one of four perennial biofuel crop treatments: 1) switchgrass monoculture, 2) warm-season grass mix (5 species), biomass mix (16 species), or prairie mix (32 species). Each of the four treatments was replicated four times on three soil types (Flagler sandy loam, Saude loam, and Spillville/Coland clay loam) for a total of 48 research plots. In each plot, a permanent 50-m transect was randomly established for sampling.

Butterfly Sampling. From June to September 2010, we conducted weekly visual surveys of butterflies by walking the established transects at a pace of 10 m/min and recording butterflies present within a 3-m² window of the recorder. Butterflies were identified without capture when possible.

Floral Resource Sampling. From 16 June to 25 July, we sampled all plots bi-weekly for available floral resources. We recorded the species richness of flowering plants and the number of ramets and inflorescences for each species in bloom in twenty 1-m² quadrats along the sampling transect. To ensure independent samples, we randomized our starting point and quadrat placement for each survey.

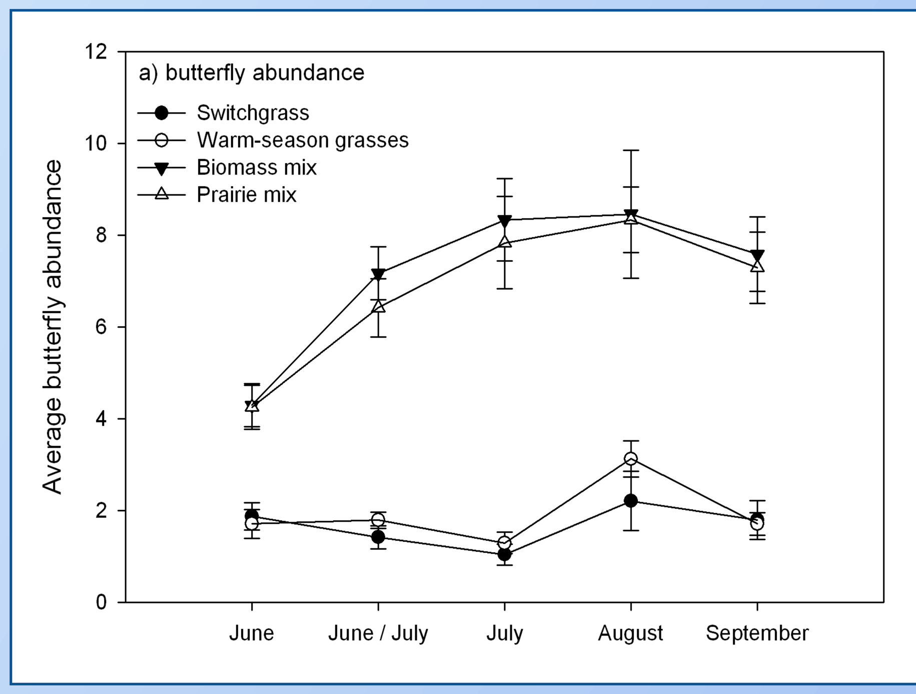

Figure 1. Average butterfly abundance was greater in Prairie and Biomass than Switchgrass and Warm-season Grass treatments.

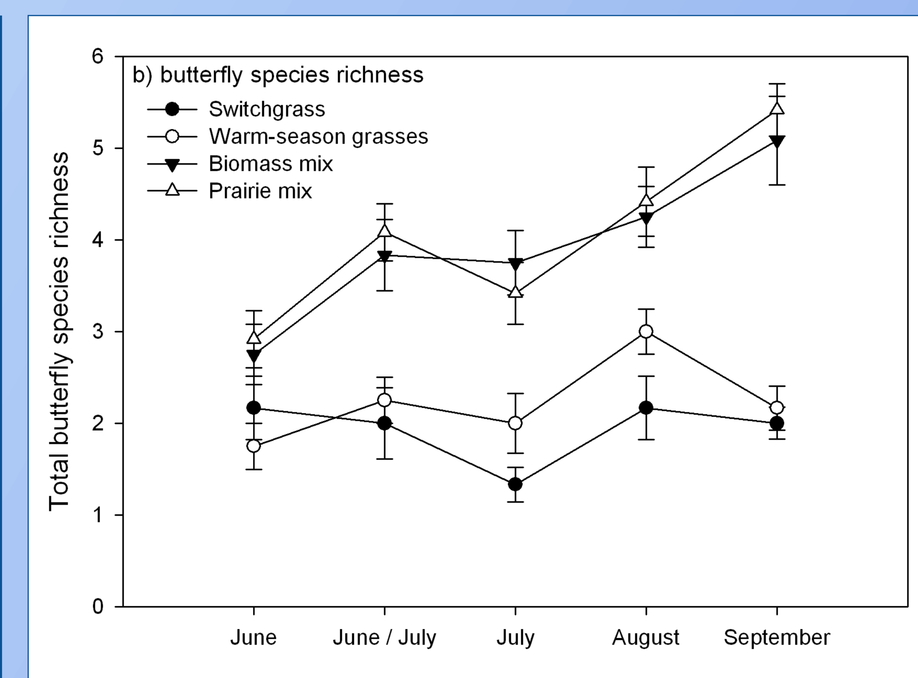

Figure 2. Total butterfly species richness was greater in Prairie and Biomass than Switchgrass and Warm -season Grass treatments.

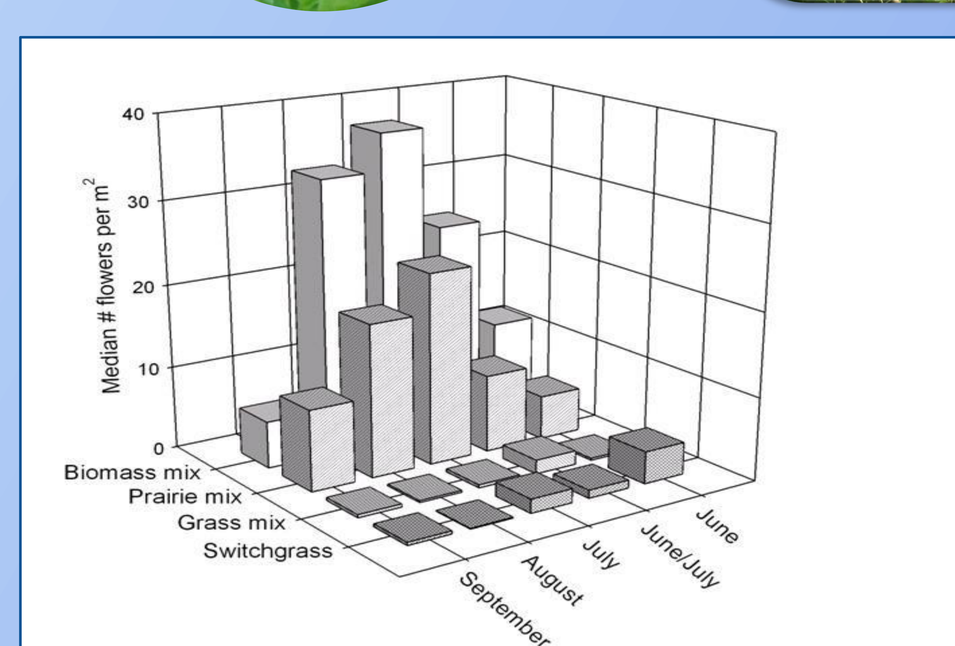

Figure 3. Median flower abundance in four biomass production treatments during the 2010 growing season.

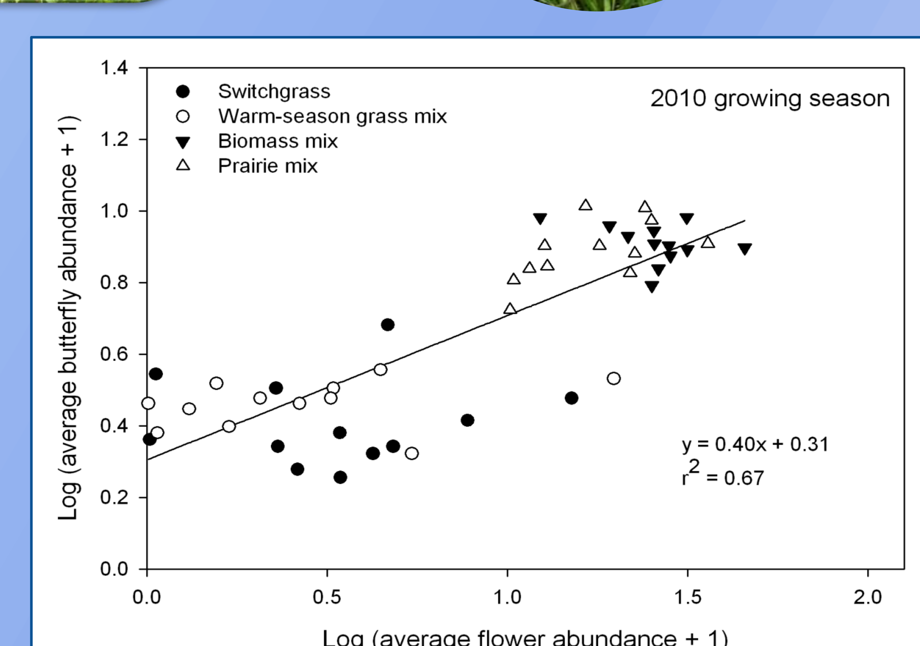

Figure 4. Linear regression of log-transformed butterfly abundance vs. log-transformed floral abundance. Approximately 67% of the variation in butterfly abundance is explained by flower abundance.

ACKNOWLEDGEMENTS

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RESULTS

Butterflies. We recorded sightings of 2,110 butterflies representing 31 species. Butterfly abundance (Fig. 1) and species richness (Fig. 2) varied over the course of the 2010 growing season. Butterfly abundance increased significantly over the course of the growing season in the biomass and prairie mix plots, peaking in either July or August depending on soil type. Species richness peaked in the biomass and prairie mix plots in September, while there was little variation in species richness over the growing season in the switchgrass and warm-season grass plots (Fig 2).

Floral Resources.
We recorded 54 forb species (17 treatment 37 non–treatment) in bloom during the 2010 growing season. The total number of species observed in bloom in each plot over the entire growing season was significantly higher in the biomass and prairie mix plots compared to the switchgrass and warm-season grass plots (Kruskall–Wallis, df = 3, H = 36.94, $p < 0.001$). In terms of floral abundance, over the entire growing season the total number of flowers in bloom was greater in the biomass mix than the prairie mix, and in the prairie mix than either the switchgrass or warm-season grass mix, which did not differ from one another (Figure 3; Kruskall–Wallis, df = 3, H = 33.98, $p < 0.001$).

We employed linear regression to relate butterfly abundance to floral resources (Figure 4). The linear regression of log-butterfly abundance against log-flower abundance was highly significant (model $F_{1,46} = 94.95$, $p<0.001$); the best fitting equation was log(butterfly abundance+1) = 0.40 x log(flower abundance+1) + 0.31; $r^2 = 0.67$).

CONCLUSIONS

We found that floral diversity directly impacts butterfly abundance and species richness when low-input high-diversity perennial native plants are managed as biofuel feedstocks. Our research demonstrates that habitat characteristics varied widely among four candidate lignocellulosic prairie biofuel crops during early establishment and that floral abundance and richness were strong predictors of butterfly abundance and richness respectively. We are preparing for a third season of surveys and expect to see further differentiation among treatments as plant communities continue to mature.

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