ABSTRACT

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Riparian buffers composed of either native warm season or non-native cool season grasses are commonly planted alongside crop fields. Although their water quality function is well documented, few studies have examined grass buffers as habitat for arthropod communities. The aerial and epigeal arthropods were surveyed using pitfall traps and sticky cards to assess the effects of both grass types on community structure in the buffer and adjacent crop. I predicted that warm season grasses would provide favorable habitat for more diverse and abundant arthropod populations, particularly natural enemies. The weight of evidence did not support my prediction and suggests that cool season grass buffers provide equivalent, if not better habitat for arthropods than warm season grasses. Coupled with higher food quality, cool season species green-up much earlier than warm season grasses in the spring and provide food resources for many herbivores and natural enemies.

ARTHROPOD COMMUNITIES IN RIPARIAN GRASS BUFFERS AND
ADJACENT CROPS

By

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Introduction

The Conservation Reserve Program (CRP) implemented by the USDA offers incentive payments to encourage farm owners to convert highly erodible and environmentally sensitive cropland to riparian habitats composed of trees, grasses, shrubs, or other approved perennial vegetative cover. Riparian habitats improve water quality by filtering nutrients and trapping sediment, provide refuge for the maintenance of biological diversity, and help to preserve the natural hydrology of a waterway (Naiman and Décamps 1997; Lovell and Sullivan 2006).

Riparian buffers are one of the many types of conservation practices available to farm owners under the CRP. These buffers are strips of permanent vegetation that are generally planted alongside environmentally sensitive areas, such as perennial and intermittent streams of forest wetlands. Currently, 28,530 ha of land are enrolled in Maryland as riparian buffers through the CRP (USDA-FSA 2007).

Seventy percent of the riparian buffers are herbaceous filter strips on the edges of working agricultural lands, of which more than 90% are located on the Eastern Shore of Maryland (USDA-FSA 2007). Herbaceous filter strips (hereafter, grass buffers) are usually planted with either warm season grasses (WSG) or cool season grasses (CSG). Common WSG in grass buffers include one or more of the following native prairie species: switchgrass (*Trypsacum dactyloides*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizavhyrium scoparium*), and indian grass (*Sorghastrum nutans*). Warm season grasses break dormancy later in the spring, grow during the hot summer months, set seed in the fall, and then become dormant during winter and most of the early spring. Although WSG are encouraged to perpetuate native species in CRP grass buffers, approximately two-thirds of the grass buffers in Maryland are planted in exotic species of cool season grasses (CSG), primarily orchardgrass (*Dactylis glomerata*), red fescue (*Festuca rubra*), and sheep fescue

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(*Festuca ovina*). Cool season grasses start their growth earlier in the spring than WSGs, set seed in early summer, and then are dormant during hot, dry months of summer until they begin growing again in the fall if moisture is adequate. Landowners prefer CSG over WSG buffers because they are less expensive, easier and quicker to establish and maintain, and often create a more aesthetic habitat.

The value of CRP grass buffers to wildlife has focused primarily on birds and less on arthropod communities. Additionally, few studies have addressed the potential effects of CRP grass buffers on the arthropod community in the adjacent crops. Chemical insecticides have been the main method for controlling most insect pests of agricultural crops in Maryland; however, heavy reliance on this single control tactic has led to the development of resistance in many pests, ground and surface water contamination, and adverse effects on non-target organisms. For these reasons, there is a need for more environmentally-friendly approaches to crop protection, including biologically-based methods of insect control (Lewis et al. 1997; Mattison and Norris 2005). The conservation and enhancement of naturally-occurring beneficial arthropods such as insect parasitoids (scelionid wasps, fairyflies, ichneumonid wasps) and predators (carabid beetles, spiders, lady beetles, rove beetles) are important biologically-based methods to maintain pest populations (grasshoppers, aphids, leafhoppers, caterpillars) below economically damaging levels (Gurr et al. 1998; Landis et al. 2000). To date, few studies have assessed the extent to which CRP grass buffers serve as propagation areas for increasing the diversity and stability of the local arthropod community, which could lead to increased natural enemy activity in adjacent crops. A number of reviews of a rapidly expanding literature on landscape ecology have shown that the surrounding, uncultivated habitats of crop systems can help to sustain the structure and function of natural enemies of agricultural pests by providing alternative food sources, prey or hosts, overwintering sites, and refuge from farming activities (see reviews in Landis et al. 2000; Maudsley 2000; Sunderland and Samu 2000; Marshall and Moonen 2002).

A majority of insect predators overwinter in non-crop grassy areas because these permanent habitats provide a more stable microclimate in the winter than sparsely vegetated crop fields (Luff 1966; Thomas et al. 1991; Landis et al. 2000). Winter survival of carabid beetles, which are important and abundant predators in many crop systems (Kromp 1999; Melnychuk et al. 2003; Witmer et al. 2003), is positively correlated with vegetation height (Dennis et al. 1994), successional age (Frank and Reichhart 2004), number of grass tussocks, and leaf litter depth (Thomas et al. 1992a) of non-crop habitats. Other predators and parasitoids are also known to overwinter in non-crop habitat (Landis and Haas 1992; Bruck and Lewis 1998; Tscharntke et al. 2002), including fairyflies (Corbett and Rosenheim 1996), lady beetles (Bianchi and Van der Werf 2003), rove beetles (Frank and Reichhart 2004), and spiders (Lemke and Poehling 2002; Pywell et al. 2005). In general, overall arthropod diversity in a crop is increased when the crop is near to uncultivated habitat with stable microclimates for overwintering (Dennis and Fry 1992).

Natural enemies can find refuge from pesticides in non-crop habitats, which act as sources for natural enemies (Thies and Tscharntke 1999; Braman et al. 2002) that disperse into the crop after a distrbance and buffer the negative effects of pesticide in the native community (Lee et al. 2001). Good and Giller (1991) reported that predatory beetles recolonize a disturbed crop more quickly in more diverse landscapes.

Predators and parasitoids also rely on the vegetational diversity of non-crop habitats to obtain resources that are not available in the crop. Many natural enemies feed on nectar (Bowie et al. 1995; Bugg et al. 1997; Landis et al. 2000; Lee et al. 2006), which may only be available in a crop for a short period of time, if at all. Non-crop habitat with flowering forbs can provide this resource, which has been shown to increase parasitoid fecundity and longevity on a more continuous basis (Idris and Grafius 1995; Landis et al. 2000). Extrafloral nectaries can also affect arthropod community dynamics, potentially enhancing the diversity and abundance of arthropods (Rudgers and Gardener 2004). Pollen can also be an important

protein resource for predators and parasitoids (Bowie et al. 1995). For example, predation

pressure from hoverflies was greater in wheat fields when they were adjacent to canola fields

where the flies were able to obtain pollen (Bowie et al. 1999; Landis et al. 2000). Similar

results were observed with ichneumonid parasitoids in broccoli adjacent to flowering

buckwheat (Lavandero et al. 2005). Overall arthropod diversity is also increased in crops

near to managed habitat providing alternative food resources (Dennis and Fry 1992). Non-

crop habitat in the landscape can also provide natural enemies with alternative hosts and prey

when the pests are not present in the crop (Landis et al. 2000; Bianchi and Van der Werf

2004). The presence of alternative prey in surrounding habitats can promote the

establishment of natural enemy populations before the pests arrive, increasing the probability

that the natural enemies will be able to maintain the pest population below economic

thresholds (Landis et al. 2000). However, the presence of shelter and food resources in non-

crop habitat does not guarantee better biological control; thus, care must be taken in selecting

forb species that are attractive and accessible to natural enemies in the agroecosystem (Idris

and Grafius 1995; Wäckers 2004), but not attractive to pest species (Landis et al. 2000).

Tussock-forming grasses, such as the native WSGs, are favorable for overwintering

arthropods because they are structurally diverse and provide relatively stable, protected

microclimates that increase the winter survival rate of arthropods (Luff 1966; Dennis and Fry

1992; Thomas et al. 1992b; Dennis et al. 1994). Grasses that grow in tussocks have also been

shown to harbor greater abundance and species richness of arthropods than grasses that cover

the habitat more uniformly (Dennis et al. 1998; Collins et al. 2003). Additionally, McIntyre

and Thompson (2003) found greater densities of spiders, beetles, orthopterans, and

lepidopterans in native warm season prairie grasses than in mixed and non-native grasses. In

general, native grasses are expected to harbor both co-evolved specialist taxa as well as

generalist invasive taxa, while generalist arthropods are thought to be more commonly found

on introduced plant species than native species (Strong et al. 1984; Lankau et al. 2004).

Additionally, WSG are more often planted in mixes with flowering forbs than are cool season grasses. These mixed vegetation habitats are expected to provide more alternative food sources such as pollen and nectar that can increase the reproductive rate of natural enemies (Baggen and Gurr 1998).

Differing management practices used in WSG and CSG buffers may also influence arthropod taxonomic richness and abundance. Community diversity of arthropods tends to be greater in moderately disturbed habitats relative to frequently disturbed habitats (DiGiulio et al. 2001). Cool season grass buffers are mowed annually, whereas warm season grass buffers are subject to less management disturbances – usually a light discing or controlled burning every 3-4 years. Furthermore, cool season grasses may be a less favorable habitat for arthropod communities due to changes in the quality and quantity of food available during the summer. These grasses are usually stressed and turn brown during hot and dry conditions, whereas WSGs are more drought tolerant, which allows plants to remain green and growing even during dry conditions.

Riparian grass buffers with an appropriate level of diversification could serve to foster large multi-species populations of natural enemies as a source of immigrants into crops. However, the conservation biological control function of CRP grass buffers currently being planted in Maryland is largely unknown. In this study, I examined the arthropod community in CRP grass buffers and the adjacent crops to address the following questions: (1) do warm season grass buffers harbor greater numbers and diversity of arthropods than cool season grass buffers, and (2) do crops adjacent to warm season grass buffers have greater numbers and diversity of arthropods than crops adjacent to cool season grass buffers? Specific emphasis was given to the influence of vegetation type on the beneficial arthropods and their potential prey. Given the differing characteristics of the vegetation types described above, I predicted that warm season grasses provide more sustainable habitat to enhance conservation biological control. The information provided by this study is needed so that

landowners, NRCS conservationists, and policy makers can make informed decisions about CRP land use and also to improve the effectiveness of riparian grass buffers as habitats to enhance conservation biological control.

Methods and Materials

Study System

With help from county NRCS conservationists, grass buffer and field sites were chosen from a list of CRP participating landowners in Queen Anne's, Talbot, and Caroline counties on the Eastern Shore of Maryland. All buffers selected were established and maintained with either warm or cool season grasses for at least 3 years and were at least 6 meters wide and 200 meters long. With landowner permission and cooperation, study sites were distributed among 15 farms. In 2003, 7 buffers of each grass type adjacent to cornfields were sampled; buffers adjacent to soybeans were not studied in 2003. In 2004, sites consisted of 13 WSG and 7 CSG buffers adjacent to corn, and 9 WSG and 15 CSG buffers adjacent to soybeans. Only 7 farms sampled in 2003 were used in 2004 as well due to management changes or changes in the adjacent crop. Each buffer-field combination served as a replicate within each year.

Arthropod Sampling Methods

Pitfall traps were used to measure the community diversity and abundance of epigeal arthropods. Traps consisted of 355-mL plastic cups containing approximately 60-mL of ethylene glycol and were embedded in the ground so that the lip of the cup was level with the ground surface. A 30-cm square plastic cover was supported by three carriage bolts approximately 2-cm above the cup to prevent weather and wildlife interference. After each sampling period, cups were brought back to the laboratory, vacuum-filtered and rinsed over

fine organdy cloth to remove the ethylene glycol. Captured invertebrates were stored in 70%
ethanol until they could be processed.

Yellow sticky cards (7.5-cm x 12.5-cm, Olson Products, Inc.) were used to measure
the relative abundance and richness of aerial arthropods in the crop and buffer canopy. Cards
were attached to a bamboo pole using wooden clothespins and positioned at canopy level in
corn through the tassel stages and then at ear level after anthesis. In soybeans, cards were
positioned at the height of the uppermost foliage. Cards in the grass buffers were placed at
the same level as the traps in the adjacent crop. Only one side of the card was exposed and
faced the crop-buffer interface. Exposed cards were placed into clear plastic resealable bags
in the field, brought back into the laboratory, and frozen until they could be processed. In the
laboratory, arthropods in each pitfall and sticky card sample were viewed under a
stereomicroscope, counted, and recorded to the order or family level.

Sampling Layout

In each buffer-field replicate, three transects of sampling sites were established
perpendicular to the crop-buffer interface, 75-100-m apart from one another and at least 50-m
from the edges of the crop field. Each transect consisted of three sampling sites; one in the
buffer and two in the crop. The buffer site was located at 6-m from the crop-buffer interface
or at half of the width of the buffers that were less than 12-m wide. Sampling sites in the
crop were at 6-m (hereafter, near site) and 46-m (hereafter, far site) from the interface. A
sticky card and pitfall trap were exposed at each sampling site for one 7-d period during the
months of June and July in 2003, and June, July, and August in 2004. August 2003 was
excluded because of abnormally heavy rains throughout most of the month.

Vegetation Measurements

The vertical density of the buffer vegetation was measured near each sampling site using a Robel pole (Robel et al. 1970) where the vegetation had not been trampled down by animal activity. Vertical density measurements were taken at the four cardinal directions and recorded as the highest obstructed point on the Robel pole visible at a height of 1-m and a distance of 4-m. Measurements at each sampling site were averaged.

A 1-m^2 frame was placed in the same general area as the Robel pole to examine non-overlapping percent canopy coverage (could not exceed 100% at a single location). Percent cover of grass species, forb species, standing dead grass, bare ground, and litter was estimated; only those plants with their base within the frame were included. All forbs that occupied more than 5% of the frame area were identified to the species level.

Statistical Analysis

The number of individuals recorded in each taxonomic group was averaged across transects for each sampling site within each buffer-field replicate to avoid pseudoreplication (Hurlbert 1984). Taxa were assigned to 1 of 4 functional groups (saprovores, herbivores, predators, or parasitoids) based on the primary ecological function of most of the members of each taxonomic group. Certain taxa were eliminated from the data analyses because there were not accurately sampled using the particular sampling method.

The composition of arthropod communities in the buffer and crop habitats was characterized by 3 diversity and community-related properties. For each sampling site, the number of families/orders recorded and the total number of arthropods captured were used to measure taxa richness and abundance, respectively. Simpson's index was used as a measure of dominance and evenness of the community and is expressed as

$$D = \sum p_i^2$$

where p_i is the proportion of individuals in the ith taxa. D is the probability that any two randomly selected individuals will belong to the same taxa group. The data were transformed using the negative natural logarithm to fix normality and variance issues. This transformation also allowed for more intuitive data interpretation because as the transformed index increased, the evenness of the assemblage also increased (Magurran 2004).

Test for significant differences between buffer types and sampling month with respect to the community properties and vegetative data were performed by mixed model ANOVA (SAS Institute 1997). Before analysis, data were tested for normality and homogenous variance using the Shapiro-Wilk W test and Spearman's rank correlation and by examining residual plots. An appropriate data transformation and/or grouping of variance were performed where necessary. For analyses of buffer and crop data, sampling month was modeled as a repeated measure and year and farm were treated as random factors. The latter accounted for variance due to possible effects that proximity and management may have on the communities in replicate fields on the same farm. For the crop data, an additional fixed factor of sampling site (near site versus far site) was included. Significant effects among means were separated by using Tukey's adjustment for pair-wise comparisons ($P \leq 0.05$).

Due to the complexity of the arthropod community data sets, multivariate techniques were used to summarize simultaneously all taxa recorded by each sampling method, thus allowing for the detection of patterns in the data and testing of buffer and crop influences on the sampled community as a whole. The matrix of taxa data collected in the buffers was subjected to redundancy analysis (RDA) using CANOCO 4.5 (ter Braak and Smilauer 2002). RDA is a constrained form of principal components analysis, analogous to a multiple linear regression for all species simultaneously, in which the ordination axes are constrained to be a linear combination of a set of explanatory variables (Legendre and Legendre 1998). Six interaction terms consisting of combinations of buffer type (cool season and warm season) and sampling month (June, July, and August) were coded as categorical explanatory variables

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and represented by a series of dummy binary variable. Year (2003 and 2004) and the adjacent crop (corn and soybeans) were coded as dummy covariables. RDA was also used to analyze and identify patterns in the sampled arthropod communities in the corn and soybean fields next to cool and warm season buffers. In these analyses, the explanatory variables were combinations of buffer type, sampling month, and sampling site; year was designated as a covariable. RDA removed the variation accounted for by covariables before determining the variation in the taxa matrix explained by the explanatory variables. In all analyses, the raw data were $\log(x + 1)$-transformed to stabilize variance and reduce the influence of dominant taxa on the ordination.

The statistical significance of the relationship between the community data and the set of explanatory variables was determined using Monte Carlo permutation testing, implemented in CANOCO. The null hypothesis was that the influence of buffer type over time on the taxa matrix was not significantly different from any random effect. This was done by generating 499 new sets of data that were equally likely under the null hypothesis, while keeping the explanatory variables fixed. The data shuffling was directed in a specific way to year effects as sources of error from the residual. Test statistics determined the significance of the first ordination axis and that of all canonical axes together. The significance level was determined by the proportion of F values greater than or equal to the F value based on the original data set.   For each analysis, the relationship between taxa scores and centroids of explanatory variables was represented in a biplot generated by CanoDraw (ter Braak and Smilauer 2002). The ordination diagram displayed the major patterns in the taxa scores that were explained by the explanatory variables. The sample scaling option was used to interpret the distances between the groups of samples associated with the explanatory variables. To make the taxa scores more comparable on the biplots, scores were divided by the standard deviation to normalize for overly abundant taxa.

Finally, the most abundant taxa that were determined to be normally distributed and clearly represented on the RDA biplot were analyzed separately using mixed model ANOVA as described above for the community parameters. Main and interaction means (± SEM) were computed from the untransformed data.

Results

Arthropod Communities in Grass Buffers

Overall Diversity of Taxonomic Groups

A total of 104,926 individuals belonging to 100 families in 13 insect orders and 7 additional arthropod classes were collected and identified in the warm and cool season buffers. Saprovores were the most abundant trophic group captured in pitfall traps (81.20%), followed by predators (14.60%), herbivores (2.61%) and parasitoids (1.59%). Herbivores were the most abundant trophic group captured on sticky cards (70.57%), followed by parasitoids (15.72%), saprovores (8.56%), and predators (5.15%).

Composition of the Epigeal Community

Table 1 lists the frequency of occurrence and average number of individuals captured per pitfall trap, pooled over grass type and sampling month. Springtails (Collembola), sowbugs (Isopoda), and crickets (Orthoptera: Gryllidae) were the most abundant saprovores, together comprising 65.20% of the athropods collected in pitfall traps in the buffer. Flies (Diptera) and soil mites (Acarina) were captured in more than two-thirds of the pitfall traps, but the numbers recorded probably underestimated their abundances in the epigeal community. The majority of flies captured in pitfall traps were primarily saprovores, because their larvae feed on the decomposing litter present in the grass buffers. Spiders (Araneida, primarily Lycosidae), ground beetles (Coleoptera: Coleoptera), ants (Hymenoptera: Formicidae), and rove beetles (Coleoptera: Staphylinidae) were the most abundant epigeal

predators in the buffers, comprising 15.52% of the total. Insect herbivores and parasitoids

were the least abundant trophic groups inhabiting the epigeal community. These arthropods

also were underestimated by the pitfall sampling method, which relies on insect activity on

the ground surface and thus is less efficient in capturing plant-dwelling and aerially-active

taxa. It is not surprising that the majority of herbivores captured were immature leafhoppers

(Homoptera: Cicadellidae) and plant bugs (Hemiptera: Miridae) with undeveloped wings.

Likewise, the major parasitoid taxa were scelionid wasps (Hymenoptera: Scelionidae) and

humpbacked flies (Diptera: Phoridae), of which many were wingless species parasitizing

hosts found the surface litter.

The structure of the epigeal community expressed as taxa richness and total

abundance was not significantly different between grass buffer types (number of taxa: $F_{(1,105)}$

= 0.30, P = 0.59; abundance: $F_{(1,105)}$ = 1.33, P = 0.25), across sampling months (number of

taxa: $F_{(2,105)}$ = 1.60, P = 0.21; abundance: $F_{(2,105)}$ = 0.77, P = 0.47), or by interaction effect of

both measures (Figures 1A, B). The number of taxa and total number of epigeal arthropods

averaged 16.29 ± 0.54 and 169.21 ± 15.28 per pitfall trap, respectively, in CSG buffers.

Numerically, taxa richness (15.81 ± 0.52) and total abundance (161.35 ± 12.25) were slightly

lower in WSG buffers. Simpson's index of evenness for the epigeal community was also not

significantly different between buffer types ($F_{(1,105)}$ = 0.02, P = 0.90), or across sampling

months ($F_{(2,105)}$ = 2.52, P = 0.09), although data suggested that taxa were more evenly

distributed in buffer communities as the season progressed (Figure 1C).

The RDA biplot displayed the overall community response as reflected by the

weighted abundances of 27 epigeal taxa analyzed by RDA, using the interaction of buffer

type and sampling month as explanatory variables (Figure 2). Only taxa with a fit of at least

3% of the variation explained by the ordination axes were included on the biplot, though all

taxa were included in the analysis. Fifteen percent of the total variance in the taxa data was

explained by the covariables (year, adjacent crop). After fitting for covariables, the first two

ordination axes explained 4.1% of the variation in the epigeal taxa data and 88.2% of the fitted data due to the explanatory variables. The plotted centroids represent the average position of the sample grouping of each interaction term and clearly separated cool and warm season grass buffers (Figure 2). The Monte Carlo permutation test (499 permutations, $P <$ 0.01) indicated that differences in taxa composition among the six sample groupings were greater than due to chance alone.

The main differences in taxa abundance were captured by the first axis which accounted for 80% of the explained variance. Sowbugs, crickets, and centipedes (Chilopoda) were more abundant in CSG buffers, particularly in July and August. Pooled over sampling month, sowbugs, crickets, and centipedes averaged 26.7, 25.6, and 1.2 per pitfall trap in cool season grasses, compared to 17.0, 17.6, and 0.6 in warm season grasses, respectively (Table 2). In WSG buffers, ants, daddy longlegs (Phalangida), humpbacked flies (Diptera: Phoridae), and rove beetles (Staphylinidae) were more abundant. Mean trap captures of 17.7 ants, 0.7 daddy longlegs, 1.4 humpbacked flies and 3.2 rove beetles were recorded in warm season grass buffers, compared to 8.2 ants, 0.2 daddy longlegs, 0.6 humpbacked flies, and 2.0 rove beetles in cool season grass buffers (Table 2). Overall trap captures of the other taxa displayed in the biplot, including fly larvae (Diptera), parasitic wasps (Hymenoptera), scarab beetles (Coleoptera: Scarabaeidae) and plant bugs, were relatively low in both buffer types. Although springtails, mites, spiders, and ground beetles were abundant surface-dwelling arthropods, densities of these taxa were not significantly influenced by the type of grass buffer and thus the ordination axes did not account for a significant portion of their variance.

Composition of the Aerial Community

The predominant herbivores, thrips (Thysanoptera: Thripidae), frit flies (Diptera: Chloropidae), and leafhoppers (Homoptera: Cicadellidae) accounted for 52.0% of the 54,543 individuals collected on sticky cards (Table 3). These arthropods were consistently captured

on more than 90% of the cards in both types of grass buffers. Other plant feeders captured

less often included gall midges (Diptera: Cecidomyiidae), picture-winged flies (Diptera:

Otitidae), whiteflies (Homoptera: Aleyroididae), aphids (Homoptera: Aphididae), and plant

bugs (Hemiptera: Miridae). It should be noted that sticky cards captured arthropods flying in

the buffer canopy and thus the data may not represent the actual composition of herbivores

feeding on plants. For this reason, wingless forms of aphids and other less mobile herbivores

were probably more abundant than indicated. Also, grasshoppers (Orthoptera: Acrididae,

Tettigonidae) frequently escaped the sticky surface of the cards, which would lead to

underestimations of their abundance.

Twenty families of parasitic wasps were represented in the aerial community, of

which scelionid wasps (Hymenoptera: Scelionidae), fairyflies (Hymenoptera: Mymaridae)

and trichogrammatid wasps (Hymenoptera: Trichogrammatidae) were the most predominant

taxa, averaging 11.6, 3.6, and 3.6 per sticky card, respectively (Table 2). Parasitic flies

(Diptera: Phoridae, Calliphoridae, Sarcophagidae, Tachinidae) were less abundant as a

functional group compared to the parasitic wasps, and many members of these fly families

are not strict parasitoids. Of the predaceous arthropods, long-legged flies (Diptera:

Dolichopodidae) were the most abundant in the aerial community, averaging 4.2 per card,

followed by spiders, hover flies (Diptera: Syrphidae), minute pirate bugs (Hemiptera:

Anthocoridae), and lady beetles (Coleoptera: Coccinellidae). The majority of spiders

captured were immatures dispersing aerially on silken threads.

Total sticky card captures of saprovorous taxa represented only 9.0% of the aerial

community, of which dark-winged fungus gnats (Diptera: Sciaridae) and minute black

scavenger flies (Diptera: Scatopsidae) comprised 52.6% of this trophic group. A feeding

guild of 11 families of fungivorous beetles was also active aerially in the buffer canopy.

Adults and larvae of most species live in the litter layer of the buffers and feed on

decomposing plant material.

Unlike the epigeal community, the structure of the aerial community differed temporally and was influenced by the type of grass buffer. The number of taxa captured by sticky cards in CSG buffers was significantly higher than the number of taxa observed in WSG buffers ($F_{(1,106)} = 16.02$, $P < 0.01$) (Figure 3A). Pooled over sampling months, the mean number of taxa per card in cool and warm season grass buffers was 31.52 ± 0.81 and 27.81 ± 0.74, respectively. Sampling month also had a significant effect ($F_{(2,106)} = 5.05$, $P < 0.01$) on taxa richness, which was highest during June and July, particularly in the cool season buffers. The total abundance of aerial arthropods in CSG buffers (188.13 ± 13.76 per card) was numerically greater than the mean number captured in WSG buffers (171.62 ± 15.87 per card), but the difference was not statistically significant ($F_{(1,106)} = 1.6$, $P = 0.21$) (Figure 3B). Overall abundance was significantly higher in June and decreased as the season progressed ($F_{(2,106)} = 12.49$, $P < 0.01$). Numbers recorded in June (212.43 ± 23.49) were almost double those in August (131.75 ± 8.66). There was no significant difference between the evenness indices of the aerial communities in cool and warm season grass buffers ($F_{(1,106)} = 0.07$, $P = 0.79$). However, as the season progressed, the evenness indices significantly increased ($F_{(2,106)} = 13.49$, $P < 0.01$), indicating that the taxa became more equally abundant (Figure 3C).

The RDA revealed more subtle differences in the aerial communities of cool and warm season grass buffers. The biplot displayed the relationship of the explanatory variables (buffer type and sampling month) with the pattern of taxa scores in ordination space (Figure 4). Only taxa with greater than 3% of the variance explained by the constrained axes were shown. Twenty-eight percent of the total variance in the taxa data was explained by the covariable (year, adjacent crop). After fitting for covariables, the first 2 axes explained 4.9% of the variation in the aerial taxa data and 91.8% of the fitted species data due to the interaction between sampling month and buffer type. Significant testing by Monte Carlo

permutations rejected the null hypothesis that there is no effect of month and buffer type on community composition (499 permutations, $P < 0.01$).

The RDA biplot clearly separated the samples from cool and warm season grass buffers and indicated which taxa were more abundant in each buffer type (Figure 4). The concordant direction of arrows on the right side of the biplot indicates that these taxa were more abundant in CSG buffers and less abundant in WSG buffers. Of the most abundant aerially-active arthropods, frit flies and scelionid wasps were missing from the biplot, indicating that neither buffer type nor sampling month significantly influenced the variance of these taxa.

Of the herbivorous insects, populations of thrips (Thysanoptera: Thripidae), aphids (Homoptera: Aphididae), and butterflies and moths (Lepidoptera) were 25.0, 64.2, and 78.8% higher in CSG buffers compared to levels in WSG buffers, particularly during July and August (Figure 4). In contrast, high populations of leafhoppers (Homoptera: Cicadellidae) were more strongly associated with WSG buffers throughout the season. The overall average number of leafhoppers per sticky card was 14.36 ± 1.89 in WSG buffers compared to an average of 8.91 ± 1.03 leafhoppers in CSG buffers.

With the exception of scelionid wasps, populations of most hymenopteran parasitoids were more abundant in CSG buffers (Figure 4). These families included gall wasps (Hymenoptera: Charipidae), trichogrammatid wasps , fairyflies, ceraphronid wasps (Hymenoptera: Ceraphronidae), and aphelinid wasps (Aphelinidae). Combined together as a functional group, an average of 13.1 parasitoids was captured per sticky card in the CSG buffers, significantly 41% higher than average captures in WSG buffers ($F_{(1,106)} = 4.18$, $P = 0.04$). Captures of humpbacked flies (Diptera: Phoridae) were explained entirely by the first axis and were also higher in the CSG buffers. The variance in parasitic flies (Diptera: Calliphoridae, Sarcophagidae, Tachinidae) were captured primarily by the second axis, which

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predicted that they were equally abundant in CSG buffers during June and in WSG buffers in July and August.

Three major predator taxa of hover flies (Diptera: Syrphidae), long-legged flies (Diptera: Dolichopodidae), and lady beetles (Coleoptera: Coccinellidae) displayed in the biplot were more abundant in CSG buffers during June and equally abundant in both buffer types during July and August. For example, captures of these predators in cool season grasses during June averaged 4.4-fold higher than captures in warm season grasses during the same month ($F_{(1,28)} = 48.4$, $P < 0.01$). Biting midges (Diptera: Ceratopogonidae) were more closely associated with CSG buffers in June and WSG buffers in July and August. The larvae of many biting midges are predators in semi-aquatic habitats where they can occur in very large numbers.

Greater than 3% of variance of 7 saprovore taxa was jointly explained by both ordination axes. Altogether, these insects were more closely associated with CSG buffers, where they averaged 15.7 compared to 10.4 per sticky card in WSG buffers. However, captures of saprovores varied with respect to both buffer type and sampling month.

Vegetative Characteristics

The vegetation in WSG buffers was both significantly taller (maximum height: $F_{(1,46)} = 294.5$, $P < 0.01$) and denser (vertical density: $F_{(1,52)} = 10.9$, $P < 0.01$) than the vegetation in cool season grass buffers. The percentage of all herbaceous flowering plants and shrubs (total forbs) was significantly higher in WSG buffers ($F_{(1,97)} = 4.93$, $P = 0.029$), indicating greater plant biodiversity. In particular, there were significantly more perennial flowers (asters, coreopis, and goldenrods) associated with the warm season grasses ($F_{(1,97)} = 22.08$, $P > 0.001$), and many of forbs were probably established as part of the initial seed mix.

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Arthropod Communities in Crops Adjacent to Grass Buffers

Overall Diversity of Taxonomic Groups

Of the 86,234 epigeal arthropods collected by pitfall traps in crop fields in 2003 and 2004, saprovores were the most abundant trophic group (83.53%), followed by predators (13.14%), herbivores (1.86%), and parasitoids (1.47%). A total of 99,278 aerial arthropods from sticky cards were collected during both years in crop fields. Of the taxa recorded, 73.67% were herbivores, 13.27% were parasitoids, 8.30% were saprovores, and 4.76% were predators.

The relative occurrence and abundance of trophic groups of epigeal invertebrates were similar among corn, soybeans, and riparian buffers. Overall, the total number of arthropods captured per pitfall trap averaged 142.3 and 140.9 in corn and soybeans, respectively, compared to an average of 152.3 in the grass buffers. However, there were noticeable differences in the composition of each feeding guild. For instance, leafhoppers, sowbugs (Isopoda), millipedes (Diplopoda), and ants were significantly more abundant in grass buffers, whereas soil mites (Acarina) and ground beetles were more numerous in the crops. Greater differences in the diversity and abundance of arthropods were evident in the aerial communities among the three habitats sampled. Sticky card captures (40.8 individuals per card) in buffers averaged 43-93% higher than the total captures in crop fields. Of the beneficial insects, minute pirate bugs and lady beetles were significantly more abundant in crop fields, whereas long-legged flies and most families of parasitic wasps (particularly scelionid wasps) occurred more frequently at higher densities in grass buffers. The frequency and abundance of most herbivorous taxa on sticky cards were similar among crops and grass buffers, except for picture-winged flies (Diptera: Otitidae) and whiteflies (Homoptera: Aleyrodidae) which occurred mainly in cornfields and soybeans, respectively. Thrips were consistently found on most sticky cards but population densities were significantly different,

averaging 51.4, 7.5, and 115.3 thrips per card in the grass buffers, corn, and soybeans, respectively.

Corn – Composition of the Epigeal Community

Springtails (Collembola), crickets (Orthoptera: Gryllidae), and soil mites comprised 79.16 % of the 61,022 epigeal arthropods in cornfields, followed by spiders, ground beetles, and rove beetles (Table 1). Consistent with pitfall data from buffers, scelionid wasps, and humpbacked flies were the only parasitoids captured in appreciable numbers in cornfields.

ANOVA results indicated no significant two-way effects of buffer type, sampling month, and sampling site on the three measured properties of community structure. The type of grass buffer adjacent to cornfields also did not have a significant effect on taxa richness ($F_{(1,132)} = 0.12$; $P = 0.73$) (Figure 5A), although the mean number of taxa per pitfall trap was greater in cornfields next to CSG buffers (15.04 ± 0.64) than in fields next to WSG buffers (11.86 ± 0.46). Sampling month had a significant effect on the invertebrate community in cornfields ($F_{(2,132)} = 6.52$; $P < 0.01$), with taxa richness increasing as the season progressed and crop biomass increased. Sampling site within cornfields did not have a significant effect on the number of taxa ($F_{(1,132)} = 0.71$; $P = 0.40$), although taxa richness was consistently higher in pitfall traps located at 6-m from the field edge (near site).

The total abundance of epigeal invertebrates captured in pitfall traps was significantly higher in cornfields associated with CSG buffers (195.60 ± 18.35) than in cornfields associated with WSG buffers (114.19 ± 11.87) ($F_{(1,132)} = 12.27$, $P < 0.01$) (Figure 5B). Sampling month and site did not have significant effects on total abundance of epigeal invertebrates in cornfields (month: $F_{(2,132)} = 1.56$, $P = 0.21$; site: $F_{(1,132)} = 1.18$, $P = 0.28$); however, consistent trends suggested that community abundance declined through the summer and was greater at the far site. Overall, pitfall sampling recorded an average of

168.15 ± 17.53 invertebrates per trap at the far site and 128.94 ± 12.22 at the near site in cornfields.

Simpson's index of evenness indicated that numbers of epigeal arthropods became more evenly distributed among the different taxa in cornfields as the season progressed ($F_{(1,132)} = 4.10$; $P = 0.02$) and evenness was significantly greater in cornfields next to warm season grass buffers ($F_{(1,132)} = 6.05$, $P = 0.02$) (Figure 5C). The main effect of sampling site on evenness was non-significant ($F_{(1,132)} = 0.00$, $P = 0.95$).

RDA captured 21.6% of the variance due to the covariables (year, sampling month), and the first two ordination axes explained 6.1% of the variation in the epigeal taxa data. When constrained by the explanatory variables, a significant 69.0% of the fitted taxa data was explained by the two axes (499 Monte Carlo permutations, $P < 0.01$). The distances between centroids of samples from cornfields next to the two buffer types were clearly separated by the first axis (Figure 6). Community composition of epigeal invertebrates was most similar in the near and far samples collected during June and July, and more dissimilar between near and far sites during August.

Data on 66 taxa of epigeal invertebrates were included in the RDA but only 15 taxa with greater than 3% of the variance explained are displayed in Figure 6. Arrow vectors in the direction of centroids show taxa that were more abundant in samples represented by those centroids. Also, taxa with longer arrows generally indicate greater differences in abundance due to the explanatory variables, particularly buffer type. Higher populations of crickets and sowbugs were clearly associated with cornfields next to CSG buffers, where pitfall captures averaged 2.8- to 6.8-fold higher than captures in cornfields next to WSG buffers. Sowbug densities in cornfields were particularly high during August at the near sites close to buffers. The arrows of 8 taxa were directed primarily toward centroids of cornfields next to WSG buffers. Captures of these taxa were generally higher in these fields but still relatively low (> 1 per trap) and infrequent. The variation in abundances of the remaining taxa was explained

primarily by the second axis, which mainly accounted for sampling month and site effects. Of these taxa, populations of springtails, scelionid wasps, and centipedes were most abundant in cornfields next to CSG buffers in June (Table 5). For instance, numbers of springtails were 2-fold higher during June in cornfields next to CSG buffers, compared to numbers captured in fields next to WSG buffers ($F_{(2,138)} = 5.48$, $P < 0.01$). Ground beetles showed the opposite response and were most abundant in August at the near site in cornfields next to CSG buffers and also in fields next to WSG buffers in June. This differential response was corroborated by a significant buffer type by month interaction effect ($F_{(2,138)} = 3.91$, $P = 0.02$). Other beneficial taxa, such as spiders and rove beetles, were among the most abundant arthropods in cornfields but their populations were not influenced by the explanatory variables.

Corn – Composition of the Aerial Community

Altogether, 59.4% of the arthropods captured on sticky cards in cornfields belonged to taxonomic groups that are primarily herbivores (Table 3). Frit flies and picture-winged flies were the most abundant, accounting for 31.24% of the 46,801 individuals recorded. Little is known about the ecological role of these flies in cornfields, although most species feed on grasses as larvae. Other relatively abundant herbivorous insects represented 13.8% of the aerial community, including more than a dozen families of Diptera and Coleoptera. Hover flies, spiders, long-legged flies, and lady beetles in order of abundance were the major predators captured on sticky cards; and together with other minor predators comprised 5.1% of the aerial invertebrates in cornfields. Consistent with the portion of parasitoids active in the grass buffers, 21.7% of the sticky card captures belonged to 10 families of parasitic hymenopterans and 4 dipteran families.

The type of adjacent grass buffer did not have a significant effect on the taxa richness of the aerial community in corn ($F_{(1,129)} = 0.27$, $P = 0.60$). (Figure 7A). The number of taxa

in fields associated with cool and warm season grass buffers averaged 27.03 and 24.39 per sticky card, respectively. Sampling month also did not have a significant effect on the number of taxa collected, though the number of taxa collected seemed to decline slightly over the season ($F_{(2,129)} = 0.94$, $P = 0.39$). The number of taxa collected at the near site was not significantly different from the number of taxa collected at the far site in cornfields ($F_{(1,129)} = 1.05$, $P = 0.31$). Overall total captures averaged 195.6 ± 18.35 and 114.2 ± 11.87 in cornfields next to cool and warm season grass buffers, respectively, though this observed difference was not significant ($F_{(1,129)} = 1.61$, $P = 0.21$). The number of aerial arthropods collected significantly declined over the season ($F_{(2,129)} = 5.21$, $P < 0.01$). There was no significant difference between the number of arthropods collected at the near site versus the far site ($F_{(1,129)} = 0.21$, $P = 0.65$). Aerial community evenness in cornfields was not significantly affected by the adjacent buffer type ($F_{(1,129)} = 0.15$, $P = 0.70$). Community evenness did significantly decline over the season ($F_{(2,129)} = 4.82$, $P < 0.01$), and evenness was significantly greater at the near location than at the far location ($F_{(1,129)} = 5.83$, $P = 0.02$) (Figure 7C).

Ordination results of the redundancy analysis were inconclusive in discerning differences in taxa abundance constrained by the interactions of buffer type, month, and sampling site. The first and second axes explained 4.2% of the variation in the aerial taxa data and 64.2% of the fitted taxa data, but the Monte Carlo test failed to indicate a significant relationship with the explanatory variables (499 permutations, $P = 0.07$). ANOVA results showed that the populations of many individual taxa significantly declined through the season. However, with the exception of a few taxa, abundances of the predominant arthropods in each trophic group were not statistically different in cornfields next to cool and warm season grass buffers. Of the beneficial insects, sticky card captures of fairyflies ($F_{(1,135)} = 6.49$, $P < 0.01$) were significantly higher in cornfields next to WSG buffers, whereas

braconid wasps ($F_{(1,125)}$ = 14.69, $P < 0.01$) and lady beetles ($F_{(2,125)}$ = 3.21, $P = 0.04$) captures were significantly higher in fields next to CSG buffers.

Soybeans – Composition of the Epigeal Community

Overall diversity and abundance of surface-dwelling arthropods in soybean fields next to grass buffers matched closely with epigeal communities in cornfields. The saprovores (primarily crickets, springtails, and soil mites) made up 74% of all insects captured in pitfall traps. Spiders, ground beetles, rove beetles, and other minor predators were second in abundance, while herbivores and parasitoids together represented < 5% of the community.

The ANOVA results show no significant differences in taxa richness of epigeal communities in soybean fields due to adjacent buffer type ($F_{(1,71)}$ = 0.57, $P = 0.45$) or sampling month ($F_{(2,71)}$ = 0.44, $P = 0.64$) (Figure 8A). However, significantly more taxa were collected in pitfall traps at the near site than at the far site ($F_{(1,71)}$ = 4.60, $P = 0.04$). The number of arthropods collected in soybeans also was not influenced by the adjacent buffer type ($F_{(1,71)}$ = 0, $P = 0.97$) but did significantly decline over the season ($F_{(2,71)}$ = 5.39, $P < 0.01$). Furthermore, average total captures at the near (138.6 ± 9.71) and far (135.6 ± 12.89) sites were not statistically different ($F_{(1,71)}$ = 0.28, $P = 0.60$) (Figure 8B). Community evenness was greater in fields next to WSG buffers during June, whereas evenness was greater in fields next to CSG buffers during July and August (interaction: $F_{(2,71)}$ = 3.18, $P = 0.05$; buffer: $F_{(1,71)}$ = 9.12, $P < 0.01$; sampling month: $F_{(2,71)}$ = 6.98, $P < 0.01$). Additionally, the effect of the interaction between sampling month and sampling site on community evenness was significant ($F_{(2,71)}$ = 7.72, $P < 0.01$), but the main effect of sampling site was not significant($F_{(1,71)}$ = 1.23, $P = 0.27$). Evenness was greater at the far site in June and July and at the near site during August (Figure 8C).

The constrained ordination analysis did not extract a significant portion of the variance in the soybean epigeal community data (499 Monte Carlo permutations, $P = 0.59$)

and thus was not able to display any taxa composition relationships among groups of fields associated with buffer types. However, ANOVA results of individual taxa yielded significant differences in the abundance of two major predator groups – ground beetles and spiders. Pooled over sampling months, pitfall captures of ground beetles averaged 9.4 and 4.4 in soybean fields next to cool and warm season grass buffers, respectively ($F_{(1,77)} = 7.1$, $P < 0.01$). The difference was almost 4-fold during June. Spiders were influenced in a similar way; in fields adjacent to CSG buffers, captures averaged 13.4 ± 3.83 compared to 6.1 ± 0.81 in fields next to CSG buffers. Abundances of other major taxa in each trophic group were unaffected by the buffer type but many showed significant changes over the season.

Soybeans – Composition of the Aerial Community

There was greater dissimilarity in the diversity of foliage-dwelling arthropods between the two crop systems than observed in the epigeal community. Five major herbivore taxa, including frit flies, leafhoppers, thrips, whiteflies, and aphids were more numerous in soybeans than in corn, comprising 84.7% of the aerial community. Similar to the corn and grass buffer communities, fairyflies, scelionid wasps, and trichogrammatid wasps were the most abundant parasitoids, and spiders, long-legged flies, and minute pirate bugs were the major predators.

Taxa richness was significantly higher in fields next to CSG buffers during June and July, while the opposite effect occurred during August when the number of taxa in soybeans was higher next to warm season grasses ($F_{(2,76)} = 6.19$, $P < 0.01$), although neither main effects were significant (buffer type: $F_{(1,76)} = 0.29$, $P = 0.59$; sampling month: $F_{(2,76)} = 2.19$, $P = 0.12$) (Figure 9A). Significantly more taxa were captured on sticky cards at the near site in soybean fields ($F_{(1,76)} = 6.19$, $P < 0.01$). This difference was most noticeable in soybean fields next to cool season grasses, but the interaction effect of sampling site and buffer type was not significant ($F_{(2,76)} = 0.49$, $P = 0.49$). Although the main effect of buffer type was not

significant ($F_{(1,76)} = 2.91$, $P = 0.09$), numerically more arthropods were captured on sticky

cards in soybeans next to CSG buffers (335.0 ± 22.7) compared with fields next to warm

season grass buffers (231.1 ± 14.7). Sampling month also did not have a significant effect on

the number of arthropods collected ($F_{(2,76)} = 0.06$, $P = 0.94$). While the numbers of

arthropods sampled adjacent to WSG buffers were similar at the near and far sites, many

more arthropods were sampled at the far site than the near site in soybean fields adjacent to

CSG buffers, leading to a significant interaction effect of buffer type and location (interaction

effect: $F_{(1,76)} = 7.31$, $P < 0.01$). The main effect of sampling site was also significant ($F_{(1,76)} =$

7.61, $P < 0.01$) (Figure 9B). Aerial arthropod community evenness in soybeans was not

significantly affected by adjacent buffer type ($F_{(1,76)} = 0.03$, $P = 0.86$) or sampling month

($F_{(2,76)} = 2.97$, $P = 0.06$). However, community evenness was greater at the near site than at

the far site ($F_{(1,76)} = 9.55$, $P < 0.01$) (Figure 9C).

The biplot in Figure 10 displays differences in the weighted abundances of aerial taxa

in soybean fields as a function of sampling month and adjacent buffer type. After fitting for

covariables (which accounted for 31.7% of the total variance in the taxa data), the

multivariate regression model explained $\geq 3\%$ of the variance of 24 taxa. The first two

ordination axes explained 6.9% of the variation in the taxa data and 53.7% of the fitted data

due to the explanatory variables. Monte Carlo permutation tests were nearly significant for

the first axis (499 permutations, $P = 0.06$), but were significant for all canonical axes together

(499 permutations, $P = 0.03$).

Community composition was most similar in soybean fields during June and more

dissimilar during July and August with respect to adjacent buffer types. Distances between

centroids of samples from the same month and buffer type also suggest considerable

dissimilarity in community composition and taxa abundances in connection with the near and

far sites. Seventeen of the taxa shown in the biplot (Fig. 10) have arrows directed toward

centroids of samples from soybean fields next to CSG buffers. This suggests that higher

abundances of many taxa in the aerial community were associated with the adjacent cool season buffers. Among these taxa were some of the most abundant herbivores, including thrips, frit flies, whiteflies, and aphids. The interaction effects of buffer type and sampling month were also significant for thrips ($F_{(2,82)} = 4.78$, $P = 0.01$) and aphids ($F_{(2,82)} = 7.8$, $P < 0.01$). Thrips and aphids were significantly more abundant during July and August in soybean fields next to CSG buffers (thrips: $F_{(2,82)} = 4.78$, $P = 0.01$; aphids: $F_{(2,82)} = 7.80$, $P < 0.01$). Natural enemies exhibited mixed results in response to the type of adjacent grass buffer. Taxa with higher abundances in fields associated with CSG buffers included humpbacked flies, aphelinid wasps, and trichogrammatid wasps, whereas parasitic flies, ladybird beetles, braconid wasps (Hymenoptera: Braconidae) and scelionid wasps were more closely associated with WSG buffers (Table 6). However, ANOVA results of individual natural enemy taxa did not reveal any significant main or interaction effects due to buffer type. Most saprovores were more abundant in soybean fields associated with cool season grass buffers, but their densities were relatively low and differences were not statistically significant.

Discussion

Arthropod Communities in Grass Buffers

This study provided evidence that the abundance and diversity of arthropods in CRP grass buffers were significantly influenced by the type of vegetation, but dissimilarities in community structure between warm and cool season grasses were greater for aerially-active arthropods than for epigeal arthropods. Taxa diversity, overall abundance of individuals, and taxa evenness in the epigeal community were not significantly different between buffer types. The abundances of a few individual taxa (ants, sowbugs, crickets) differed and were

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significantly separated on the RDA biplot. For example, ants were twice as abundant in WSG

buffers, where their nesting and foraging behavior may be favored by the tussock-forming

grasses. Although listed as predators, the role of ants in conservation biological control is

unclear because many species are omnivorous or strict seed feeders. Sowbugs and crickets

were significantly more abundant in CSG buffers, possibly because of higher quality plant

tissue (see below) and favorable habitat created by the accumulation of decomposing plant

material from annual mowing. However, the majority of the most abundant saprovores

(springtails, mites) were unaffected by the type of vegetation.

With the exception of rove beetles, which favored WSG buffers, the 2 most abundant

predator taxa, ground beetles (Coleoptera: Carabidae) and spiders (Araneida), were not

significantly influenced by buffer type, even though there were canopy structure differences

between the grass habitats which are known to affect their abundance. Studies have shown

that pitfall captures of ground beetles are higher in open habitats compared to captures in

more dense habitats (Melbourne 1999; Phillips and Cobb 2005). The average vegetation

height of WSG buffers was about 2 ½ times higher than the height of CSG buffers, and the

Robel estimates of cover indicated that WSG buffers were significantly more dense than CSG

buffers. Ground beetles were captured in greater numbers and in a higher proportion of traps

in the more open canopies of CSG buffers but differences were not significant. Spiders were

numerically more abundant in WSG buffers, particularly during July, but the overall buffer

effect was not significant due to high variance. Spiders often aggregate in habitats rich in leaf

litter-detritus in many grassland and forest habitats (Miyashita et al. 2003; Langellotto and

Denno 2004). Although the amount of surface litter was not measured, WSG buffers probably

accumulate a deeper layer of litter-detritus because their end-of-season aboveground biomass

is nearly three times greater than CSG buffers (Tufekcioglu 2000).

Analysis of the aerial community showed that CSG buffers supported 13% more taxa

and 11% more abundant populations than WSG buffers, especially during June and July. The

overall number of taxa collected on sticky cards significantly decreased over the season, as did the total number of arthropods. The evenness of abundances among taxa also significantly increased but was not different between buffer types. The abundances of the majority of arthropods displayed on the RDA biplot were more closely associated with CSG buffers. Leafhoppers (Cicadellidae), which are a highly diverse group of sap-sucking insects, were strongly associated with WSG buffers. Although individual leafhoppers were not identified to the species level, many species are host-specific and have been associated with the native prairie grasses over a long period of evolutionary time.

Aphids (Homoptera: Aphididae) and thrips (Thysanoptera: Thripidae) were common in both vegetative types, comprising 54% of all herbivores captured; however, they were more closely associated with CSG buffers, particularly during July and August. Additionally, 78.8% more lepidopteran adults were captured on sticky cards in CSG buffers compared to levels in WSG buffers. Although larval stages of these insects were seldom captured by sticky cards due to their foraging behavior, it is assumed that adult densities directly reflected levels of larval populations. These 3 herbivore groups provided the most abundant prey available for many natural enemies. Of the beneficial arthropods, the numbers of hymenopteran parasitoids (with the exception of scelionid wasps) captured on sticky cards in CSG buffers were 41% higher than captures in WSG grass buffers. Of this functional group, 4 families including gall wasps, fairyflies, ceraphronid wasps, and aphelinid wasps contributed the majority of individuals captured in grass buffers and are known to parasitize a wide range of egg and larval hosts. Scelionid wasps were particularly more abundant in WSG buffers during 2004, although the RDA analysis was unable to capture enough variation in this family to show a significant association with warm season grasses. Scelionidae is a large family of parasitic Hymenoptera whose members specialize in egg parasitism of many species of insects and arachnids. Of the predator taxa, hover flies (Diptera: Syrphidae), long-legged flies (Diptera: Dolichopodidae), and lady beetles (Coleoptera: Coccinellidae) were

more than 4-fold more abundant in CSG during June and then were more equally captured on sticky cards in both buffer types during July and August. Overall, the total abundance of beneficial arthropod taxa was significantly higher in CSG buffers, particularly during June.

In this study, I predicted that CRP buffers consisting of native, warm season grasses would be more amenable to conservation biological control by providing favorable habitat for diverse and abundant arthropod populations, particularly natural enemies. The rationale underlying this prediction is that WSG buffers provide a more diverse habitat, both structurally and in terms of plant species richness because they generally include more flowering forbs in the planting mixes. Insect diversity is frequently correlated with the diversity of plants (Schowalter 1995, Siemann et al. 1998) and architectural complexity of a habitat (Strong et al. 1984). WSG buffers also are thought to provide a more stable environment because plants are less stressed during the summer and only moderately disturbed by management practices. Native grasses also are expected to harbor both co-evolved specialist taxa as well as generalist invasive taxa, while generalist arthropods are thought to be more commonly found on the non-native, cool season grasses (Strong et al. 1984; Lankau et al. 2004). This hypothesis asserts that non-native plant species were introduced without their co-evolved specialist herbivores and thus should have lower loads of generalist herbivores than native plants. There are 2 reasons for this: first, the behavioral constraint hypothesis which states that herbivores avoid plants to which they are unaccustomed, and second, the novel defense hypothesis which states that exotic plants have defenses that native herbivores cannot tolerate (Lankau et al. 2004). Some have found these hypotheses to be true (Leger and Forister 2005), while several case studies have rejected these hypotheses (Lankau et al. 2004).

The weight of evidence in this study, especially based on the aerial community data, does not support these predictions and suggests that CSG buffers provide equivalent, if not better habitat for arthropods, particularly for herbivores and natural enemies. Many exotic

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plants can host a diverse assemblage of native herbivores (Maron and Vilà 2001), and can be at least as susceptible to herbivores in the introduced range compared to the native range (Agrawal and Kotanen 2003; Wolfe et al. 2004; Cripps et al. 2006). In addition, many of the non-native species in CSG buffers have been used in the United States as forage grasses for many years. For example, orchardgrass (*Dactylis glomerata*) was introduced in 1760 (Sullivan 1992), allowing plenty of time for native herbivores to colonize this grass species as a suitable food source and to adapt to any remaining natural defenses that orchardgrass might express.

Cool-season grasses also differ from warm-season grasses in physiology and phytochemistry. CSGs are C3 plants adapted for cooler conditions, while WSGs have the C4 photosynthetic system that favors higher temperatures (Pearcy et al. 1981, Pearcy and Ehleringer 1984, Ehleringer et al. 1997). Due to differences in photosynthesis efficiency, leaf anatomy, and greater carbon allocation to non-leaf structures (Akin 1989), warm season grasses generally have lower-quality tissues than do cool-season grasses because of their relatively low nutritional value and abundant refractory components such as silica (Cid et al. 1989, Tscharntke and Greiler 1995). Silica in grasses is an effective feeding deterrent against chewing insects due to increased abrasiveness and also possible reduced digestion efficiency (Massey et al. 2006). In addition, lignin concentration is higher (44% more on average) and nitrogen content is lower (28% less) in warm-season grasses than in the cool-season grasses (derived from Miller 1958). Given these characteristics, CSG in CRP buffers probably provides more palatable and nutritious leaf tissue for herbivores, particularly sucking arthropods such as aphids and thrips. The non-native grasses also are likely to have fewer natural defenses against herbivory due to their more extensive plant breeding compared to native grasses which are typically highly defended, primarily by structural defenses.

Coupled with higher food quality, the phenology of CSG buffers favors earlier colonization and build-up of herbivore and natural enemies compared to WSG buffers. Cool

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season species such as orchardgrass and fescues green-up much earlier than warm season grasses in the spring and also maintain some aboveground green tissue during the winter, which provides food resources for cold-adapted insects such as aphids and certain mites. The difference in early season phenology is a main reason why herbivore abundance in CSG buffers was much higher in June compared to abundance in WSG buffers. Consequently, there was apparently more rapid establishment in natural enemy communities in CSG buffers due to a numerical response of the predators and parasitoids to the greater density of prey and hosts.

For the purpose of enhancing conservation biological control, manipulations of CSG buffers with the addition of floral resources to encourage early season activity of natural enemies may be potentially more effective than manipulations of WSG buffers. In this study, abundance of natural enemy communities in WSG buffers became more comparable to communities in CSG buffers as the cool season grasses set seed and entered dormancy later in the season. However, enhancement of predators and parasitoids at this time may be too late to effectively suppress pest populations in crop fields. For this reason, the typical practice of mowing CSG buffers in late August may have minimal adverse disruptive effect on natural enemies because many parasites and predators may already be emigrating due to the declining food quality of the senesced cool season grasses. Thorbek and Bilde (2004) found that removal of grass causes the emigration of arthropod predators, so it is possible that mowing CSG buffers could force natural enemies into adjacent crop fields to help suppress late season pests.

Arthropod Communities in Crops Adjacent to Grass Buffers

The type of grass buffer had a significant influence on taxa richness and abundance of arthropod communities in adjacent crops, particularly during June and July when many trophic groups were colonizing fields. The total abundance of epigeal arthropods was 42%

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higher in cornfields next to CSG buffers compared to fields next to WSG buffers. This difference was largely due to 2.8- to 6.8-fold higher populations of crickets and sowbugs. In soybean fields next to CSG buffers, pitfall trap captures of predaceous ground beetles and spiders were about 2-fold higher than in fields next to WSG buffers. For the aerially-active arthropods, taxa richness and total abundance were also consistently higher in crop fields at sampling sites closest to the field edge next to CSG buffers. However, most of these differences were due to captures of herbivores and saprovores and not natural enemies, which exhibited mixed results in response to the type of grass buffer associated with crop fields.

Few significant differences in community structure and taxa abundances were found between near and far sampling locations in either crop type using either sampling method. Generally, there were more arthropods collected at the near location early and late in the season, which could indicate seasonal interchange of populations between the grass buffer and crop field. With the exception of a few taxa, the composition and relative abundances of most epigeal and aerial-active taxa in crop fields corresponded to the composition and relative abundances of those taxa in the adjacent grass buffers, suggesting population linkage and movement of these taxa between habitats. Although many arthropods overwinter within the crop, particularly in the no-till situation of the fields sampled in this study (Dennis and Fry 1992), there is likely considerable movement both ways between the crop field and grass buffer. However, this study could not determine the direction and amount of movement, nor ascertain the extent at which CRP grass buffers influence arthropod communities in crop fields or vice versa. It is suggested that field edge trapping using directional pitfall traps would be a better approach to measure epigeal community movement between the crop and margin habitats (Thomas and Marshall 1999), but unfortunately this method was impractical in the current study.

Management Recommendations

The most striking finding of this study was that non-native CSG buffers do in fact support more abundant beneficial arthropod communities early in the season and thus may actually be more sustainable for enhancing conservation biological control. The general policy in CRP planning has been to encourage mixes of native grasses and flowering forbs in riparian buffers, whereas cool season buffers are usually planted mixed only with legumes. There is abundant evidence from other studies that non-cropped grass areas can enhance biological control in agricultural crops (Corbett and Rosenheim 1996; Gurr et al. 1998; Landis et al. 2000; Braman et al. 2002). Therefore, the addition of perennial flowering forbs to CSG buffers may be a more effective way to enhance conservation biological control by providing pollen and nectar for natural enemy populations in the early season when these food resources are most needed. Given the current focus on conservation practices throughout the Mid-Atlantic area, there is great opportunity to examine and implement practices that increase the potential influence of CRP grass buffers in this context. There is also a clear need for further studies to examine the movement of beneficial arthropods between buffer and crop habitats. Studies of arthropod communities in CRP grass buffers will be most informative if the dynamics of population interaction with crop habitats are taken into account.

Appendix: Tables

Table 1. Frequency of occurrence (freq.) and average number of individuals (avg.) per trap of the most frequent arthropods captured in pitfall traps by habitat type. Data were derived from data sets pooled over 2003 and 2004, buffer types, and sampling sites in Caroline, Talbot, and Queen Anne Counties in Maryland.

		Buffer		Corn		Soybeans		Total	
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Herbivores									
Diptera	*adults, misc.*	77.50%	4.41	65.64%	3.33	77.71%	4.59	72.08%	3.95
Stylommatophora		41.88%	2.19	32.94%	0.99	18.29%	0.33	33.26%	1.28
Coleoptera	Scarabaeidae	15.00%	0.29	17.06%	0.50	27.43%	0.54	18.32%	0.43
	Elateridae	8.75%	0.14	8.77%	0.11	20.57%	0.33	11.01%	0.16
Homoptera	Cicadellidae	26.88%	1.04	5.92%	0.10	5.71%	0.07	13.20%	0.42
Hemiptera	Miridae	20.31%	0.84	6.40%	0.27	8.57%	1.38	11.67%	0.68
Saprovores									
Collembola		94.69%	59.49	89.81%	51.54	90.86%	36.10	91.71%	51.37
Gryllidae	Gryllidae	87.81%	21.48	78.67%	40.93	98.29%	51.05	85.61%	36.07
Isopoda		71.88%	21.68	24.64%	2.65	33.71%	2.95	42.86%	9.35
Acarina		69.06%	7.32	64.93%	22.00	73.71%	16.85	68.05%	15.89
Diplopoda		34.69%	4.53	13.98%	0.45	25.71%	1.47	23.45%	2.07
Coleoptera	Cryptophagidae	9.69%	0.15	14.22%	0.47	12.57%	0.19	12.32%	0.31
	Nitidulidae	9.06%	0.10	16.35%	0.40	4.00%	0.06	11.45%	0.23
Predators									
Araneidae		90.00%	5.81	77.01%	5.98	92.00%	9.18	84.41%	6.53
Coleoptera	Carabidae	73.75%	2.94	72.04%	5.02	87.43%	8.72	75.57%	5.00
	Staphylinidae	62.19%	2.62	46.92%	3.13	50.86%	2.29	53.00%	2.79
Hymenoptera	Formicidae	72.19%	13.06	35.55%	1.48	38.86%	1.50	48.96%	5.52
Chilopoda		28.75%	0.87	26.30%	0.65	25.71%	0.50	27.04%	0.70
Phalangida		17.19%	0.48	13.27%	0.27	22.29%	0.44	16.36%	0.38
Parasitoids									
Hymenoptera	*adults, misc.*	18.75%	0.35	14.93%	0.23	13.71%	0.29	16.03%	0.28
	Scelionidae	46.56%	1.46	34.12%	1.08	49.14%	1.48	41.33%	1.29
Diptera	Phoridae	27.19%	1.01	24.17%	0.69	24.00%	0.62	25.19%	79.06

Table 2. Frequency of occurrence (freq.) and average number of individuals (avg.) per trap of the most frequent arthropods captured in cool and warm season grass buffers in 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland. Data were derived from data sets pooled over 2003 and 2004 for each sampling method.

		Pitfall				Sticky			
		Cool Season		Warm Season		Cool Season		Warm Season	
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Herbivores									
Thysanoptera	Thripidae	--	--	--	--	98.68%	53.61	98.20%	49.41
Homoptera	Cicadellidae	22.44%	0.58	31.10%	1.48	90.73%	9.65	98.20%	14.13
	Aphididae	--	--	--	--	77.48%	9.64	83.23%	5.87
	Aleyrodidae	--	--	--	--	64.90%	6.84	64.67%	7.76
	Cercopidae	--	--	--	--	5.96%	0.14	14.97%	0.71
	Membracidae	--	--	--	--	5.96%	0.47	13.77%	1.03
	Psyllidae	--	--	--	--	6.62%	0.07	5.39%	0.10
Diptera	*adults, misc.*	76.92%	4.97	78.05%	3.88	7.28%	0.13	11.38%	0.12
	larvae, misc.	5.77%	2.96	5.49%	0.19	--	--	--	--
	Chloropidae	--	--	--	--	100.00%	26.72	98.80%	24.96
	Cecidomyiidae	--	--	--	--	58.94%	2.00	67.66%	1.90
	Otitidae	--	--	--	--	35.10%	1.19	40.72%	1.47
	Tephritidae	--	--	--	--	3.31%	0.04	7.19%	0.08
	Agromyzidae	--	--	--	--	1.99%	0.03	5.99%	0.10
Stylommatophora		51.28%	3.19	32.93%	1.24	--	--	--	--
Lepidoptera	*adults, misc.*	--	--	--	--	36.42%	0.93	36.53%	0.52
	larvae, misc.	7.69%	0.98	9.15%	0.16	25.83%	0.36	14.37%	0.20
Hemiptera	Miridae	17.31%	0.77	23.17%	0.91	27.15%	0.46	37.13%	0.69
Coleoptera	Chrysomelidae	--	--	--	--	15.23%	0.26	19.16%	0.23
	Scarabaeidae	12.18%	0.22	17.68%	0.36	--	--	--	--
	Mordellidae	--	--	--	--	8.61%	0.13	14.37%	0.21
	Elateridae	8.33%	0.10	9.15%	0.18	7.28%	0.08	3.59%	0.04
Orthoptera	Tettigonidae	--	--	--	--	10.60%	0.17	11.98%	0.17
	Acrididae	--	--	--	--	8.61%	0.11	2.40%	0.03
Hymenoptera	Apiodea	--	--	--	--	5.30%	0.10	6.59%	0.19
Predators									
Araneida		90.38%	4.70	89.63%	6.87	65.56%	1.36	62.87%	1.94
Phalangida		7.69%	0.22	26.22%	0.74	--	--	--	--
Coleoptera	Carabidae	75.64%	3.16	71.95%	2.73	4.64%	0.05	4.79%	0.05
	Staphylinidae	55.13%	2.01	68.90%	3.20	18.54%	0.25	17.96%	0.26
	Coccinellidae	--	--	--	--	15.89%	0.23	8.38%	0.13
	Lampyridae	2.56%	0.13	7.93%	0.44	--	--	--	--
	Cantharidae	5.77%	0.10	3.66%	0.06	--	--	--	--
Hymenoptera	Formicidae	62.18%	8.17	81.71%	17.70	--	--	--	--
Diptera	Dolichopodidae	--	--	--	--	74.83%	4.06	61.08%	4.29
	Ceratopogonidae	--	--	--	--	50.99%	2.25	59.88%	2.17
	Syrphidae	--	--	--	--	26.49%	1.30	14.97%	0.43
Chilopoda		34.62%	1.17	23.17%	0.58	66.00%	0.01	--	--
Hemiptera	Anthocoridae	--	--	--	--	19.21%	0.32	13.17%	0.19
	Pentatomidae	5.77%	0.10	8.54%	0.59	--	--	--	--
	Lygaeidae	7.05%	0.28	4.88%	0.07	--	--	--	--
Neuroptera	Chrysopidae	9.62%	0.10	8.54%	0.10	--	--	--	--

Table 2 continued.

		Pitfall				Sticky			
		Cool Season		Warm Season		Cool Season		Warm Season	
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Saprovores									
Collembola		96.15%	53.70	93.29%	64.99	--	--	--	--
Orthoptera	Gryllidae	91.67%	25.57	84.15%	17.59	--	--	--	--
	Blattidae	10.90%	0.19	8.54%	0.13	--	--	--	--
Diptera	Sciaridae	--	--	--	--	77.48%	4.33	80.84%	3.91
	Scatopsidae	--	--	--	--	58.28%	4.15	58.08%	3.90
	Chironomidae	--	--	--	--	43.71%	1.07	45.51%	1.53
	Muscidae	--	--	--	--	15.89%	0.37	23.35%	0.76
	Psychodidae	--	--	--	--	25.17%	3.58	14.97%	1.60
	Drosophilidae	--	--	--	--	15.23%	0.22	16.17%	0.20
	Mycetophilidae	--	--	--	--	11.92%	0.37	10.18%	0.29
	Sphaeroceridae	--	--	--	--	11.92%	0.24	5.99%	0.10
Isopoda		74.36%	26.65	69.51%	16.95	--	--	--	--
Acarina		71.15%	6.74	67.07%	7.87	--	--	--	--
Diplopoda		32.69%	4.27	36.59%	4.79	--	--	--	--
Psocoptera	Psocidae	--	--	--	--	25.83%	0.40	19.16%	0.31
Coleoptera	*adults, misc.*	--	--	--	--	11.26%	0.15	6.59%	0.12
	larvae, misc.	3.21%	0.04	8.54%	0.56	--	--	--	--
	Orthoperidae	--	--	--	--	37.09%	0.97	23.35%	0.38
	Phalacridae	7.05%	0.11	6.10%	0.08	23.84%	0.48	28.74%	0.52
	Cryptophagidae	10.26%	0.15	9.15%	0.15	11.26%	0.15	10.78%	0.15
	Nitidulidae	9.62%	0.10	8.54%	0.10	--	--	--	--
	Mycetophagidae	7.05%	0.09	3.66%	0.06	--	--	--	--
	Oedemeridae	--	--	--	--	5.30%	0.05	2.40%	0.02
	Derodontidae	--	--	--	--	7.28%	0.07	2.40%	0.03
Parastioids									
Hymenoptera	*adults, misc.*	17.95%	0.36	19.51%	0.34	11.92%	0.15	8.98%	0.14
	Scelionidae	37.82%	1.15	54.88%	1.76	94.04%	6.59	96.41%	16.17
	Mymaridae	--	--	--	--	83.44%	3.67	81.44%	3.52
	Trichogrammatidae	--	--	--	--	80.13%	3.86	81.44%	3.41
	Braconidae	--	--	--	--	52.98%	1.74	46.11%	0.83
	Hymenoptera	--	--	--	--	45.70%	2.05	34.73%	0.58
	Ceraphronidae	--	--	--	--	44.37%	1.29	35.93%	0.86
	Encyrtidae	--	--	--	--	36.42%	1.85	41.92%	2.65
	Eulophidae	--	--	--	--	25.17%	0.77	34.13%	1.00
	Diapriidae	--	--	--	--	15.23%	0.19	23.95%	0.37
	Pteromalidae	--	--	--	--	9.93%	0.19	13.77%	0.22
	Aphelinidae	--	--	--	--	13.91%	0.49	5.99%	0.10
	Chalcidae	--	--	--	--	7.95%	0.15	8.98%	0.16
	Betylidae	--	--	--	--	5.30%	0.08	8.38%	11.38
	Eupelmidae	--	--	--	--	5.30%	0.09	1.80%	0.02
Diptera	Calliphoridae/ Sarcophagidae/ Tachinidae	--	--	--	--	71.52%	4.77	7.66%	4.98
	Phoridae	24.36%	0.64	29.88%	1.36	74.83%	3.81	60.48%	1.72

Table 3. Frequency of occurrence (freq,) and average number of individuals (avg.) per trap of the most frequent arthropods captured on sticky cards by habitat type. Data were derived from data sets pooled over 2003 and 2004, buffer types, and sampling sites in Caroline, Talbot, and Queen Anne's Counties in Maryland.

		Buffer		Corn		Soybeans		Total	
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Herbivores									
Diptera	Chloropidae	99.37%	25.80	97.92%	17.55	96.88%	42.74	98.20%	25.47
	Cecidomyiidae	63.52%	1.95	60.19%	1.47	51.56%	1.11	59.55%	1.56
	Otitidae	38.05%	1.33	70.37%	16.29	41.15%	0.93	53.50%	8.11
Homoptera	Cicadellidae	94.65%	12.00	96.99%	12.48	99.48%	23.02	96.71%	14.47
	Aleyrodidae	64.78%	7.32	56.71%	4.50	88.02%	41.58	65.82%	13.01
	Aphididae	80.50%	7.66	37.27%	0.95	85.94%	8.73	61.78%	4.80
Thysanoptera	Thripidae	98.43%	51.41	80.32%	7.48	97.92%	115.34	90.02%	44.29
Hemiptera	Miridae	32.39%	0.58	33.56%	1.19	52.08%	1.58	36.94%	1.06
Lepidoptera	*adults, misc.*	36.48%	0.72	8.80%	0.14	49.48%	0.90	26.43%	0.49
	larvae, misc.	19.81%	0.27	7.18%	0.09	2.60%	0.03	10.51%	0.14
Coleoptera	Chrysomelidae	17.30%	0.25	30.09%	0.81	14.06%	0.18	22.51%	0.49
Orthoptera	Tettigonidae	11.32%	0.17	11.57%	0.20	16.67%	0.34	12.53%	0.22
Saprovores									
Diptera	Sciaridae	79.25%	4.11	71.99%	3.17	75.52%	3.42	75.16%	3.54
	Scatopsidae	58.18%	4.02	32.64%	1.83	61.98%	3.92	48.24%	2.99
	Chironomidae	44.65	1.31	32.41	0.74	34.38%	0.93	36.94%	0.97
	Muscidae	19.81%	0.58	17.13%	0.31	27.60%	1.22	20.17%	0.59
	Drosophilidae	15.72%	0.21	23.38%	0.58	15.63%	0.23	19.21%	0.38
	Psychodidae	18.87%	2.53	15.74%	2.72	5.21%	0.06	14.65%	2.11
Coleoptera	Orthoperidae	29.87%	0.66	56.48%	1.61	35.94%	1.15	43.31%	1.20
	Phalacridae	26.42%	0.50	53.70%	1.27	17.71%	0.21	37.15%	0.79
Psocoptera	Psocidae	22.33%	0.35	35.65%	0.60	22.40%	0.33	28.45%	0.46
Predators									
Araneida		64.15%	1.66	55.56%	0.95	66.15%	1.45	60.62%	1.30
Diptera	Dolichopodidae	67.61%	4.18	37.27%	0.91	52.08%	2.60	50.53%	2.36
	Ceratopogonidae	55.66%	2.21	53.47%	2.20	32.29%	0.66	49.89%	1.89
	Syrphidae	20.44%	0.84	20.60%	1.31	18.75%	0.43	20.17%	0.97
Hemiptera	Anthocoridae	16.04%	0.25	45.60%	1.27	37.50%	0.66	33.97%	0.80
Coleoptera	Chrysomelidae	11.95%	0.18	39.58%	0.72	21.35%	0.28	26.54%	0.44
	Staphylinidae	18.24%	0.25	15.28%	0.19	25.00%	0.33	18.26%	0.24
Parastioids									
Hymenoptera	Scelionidae	95.28%	11.62	78.70%	2.42	86.98%	3.37	85.99%	5.72
	Mymaridae	82.39%	3.59	83.56%	4.70	85.42%	3.52	83.55%	4.08
	Trichogrammatidae	80.82%	3.63	63.66%	2.91	64.58%	2.35	69.64%	3.04
	Braconidae	49.37%	1.26	37.96%	0.79	32.81%	0.43	40.76%	0.88
	Ceraphronidae	39.94%	1.06	25.23%	0.59	32.81%	0.51	31.74%	0.73
	Charipidae	39.94%	1.28	31.48%	0.63	14.58%	0.17	30.89%	0.75
	Encyrtidae	39.31%	2.27	14.12%	0.24	31.77%	0.59	26.22%	0.99
	Eulophidae	29.87%	0.89	23.61%	0.51	23.44%	0.33	25.69%	0.60
	Diapriidae	19.81%	0.28	9.49%	0.14	15.63%	0.18	14.23%	0.20
Diptera	Calliphoridae/ Sarcophagidae/ Tachinidae	74.21%	4.88	66.90%	8.09	53.13%	2.43	66.56%	5.85
	Phoridae	67.30%	2.71	68.75%	2.19	52.08%	1.38	64.86%	2.20

Table 4. Mean vegetation height, vertical density and composition of cool and warm season grass buffers surveyed in August 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland.

	Cool Season Grass Buffers		Warm Season Grass Buffers	
	Mean (SE)	Range	Mean (SE)	Range
Height of Live Vegetation	82.4 cm (2.8cm)	45.0cm - 145.0cm	199.1cm (7.1cm)	85.0cm - 267.0cm
Vertical Density	41.3 cm (2.8cm)	3.8cm - 121.3cm	75.0cm (5.8cm)	18.8cm - 148.8cm
Cool-season Grasses	52.5% (2.3%)	10% - 99%	5.1% (2.7%)	0% - 83%
Orchardgrass	*33.5% (3.9%)*	*0% - 82%*	*0.4% (0.3%)*	*0% - 10%*
Red Fescue	*15.1% (3.2%)*	*0% - 75%*	*4.5% (2.4%)*	*0% - 73%*
Foxtail	*3.9% (2.1%)*	*0% - 99%*	*0.3% (0.3%)*	*0% - 10%*
Warm-season Grasses	0% (0%)	0%	44.0% (4.7%)	0% - 80%
Big Bluestem	*0% (0%)*	*0%*	*24.0% (4.7%)*	*0% - 75%*
Little Bluestem	*0% (0%)*	*0%*	*4.6% (2.4%)*	*0% - 55%*
Switchgrass	*0% (0%)*	*0%*	*10.4% (3.3%)*	*0% - 65%*
Dead Standing Grass	14.2% (1.3%)	0% - 50%	4.1% (1.3%)	0% - 30%
Open Space	20.7% (1.4%)	1% - 68%	14.1% (1.9%)	0% - 45%
Litter	*17.1% (1.1%)*	*0% - 40%*	*11.6% (1.3%)*	*0% - 30%*
Bare Ground	*3.6% (0.9%)*	*0% - 48%*	*2.5% (1.0%)*	*0% - 25%*
Total Forbs	10.7% (1.8%)	0% - 80%	18.4% (3.4%)	0% - 75%
Seeded Legumes	*3.9% (1.0%)*	*0% - 50%*	*7.8% (2.3%)*	*0% - 40%*
Clover	3.4% (0.9%)	0% - 50%	0.8% (0.7%)	0% - 25%
Partridge Pea	0% (0%)	0%	1.2% (0.6%)	0% - 15%
Lespedesia	0.5% (0.5%)	0% - 30%	5.9% (2.3%)	0% - 40%
Seeded Forbs	*0.2% (0.1%)*	*0% - 6%*	*7.4% (2.8%)*	*0% - 75%*
Aster	0.1% (0.1%)	0% - 6%	0.9% (0.4%)	0% - 10%
Coreopsis	0% (0%)	0%	0.9% (0.7%)	0% - 25%
Goldenrod	0.1% (0.1%)	0% - 5%	5.6% (2.5%)	0% - 75%
Weedy Forbs	*2.4% (0.6%)*	*0% - 20%*	*2.4% (1.2%)*	*0% - 40%*
Morning Glory	0.3% (0.2%)	0% - 10%	0% (0%)	0%
Horse Nettle	1.2% (0.5%)	0% - 20%	0% (0%)	0%
Mugwort	0% (0%)	0%	0.7% (0.7%)	0% - 25%
Trumpet Vine	0% (0%)	0%	0.4% (0.4%)	0% - 15%
Shrubs	*0.03% (0.02%)*	*0% - 1%*	*1.5% (0.8%)*	*0% - 25%*
Blackberry	0% (0%)	0%	1.2% (0.8%)	0% - 25%
Unidentified Forbs	*4.3% (1.1%)*	*0% - 60%*	*0.8% (0.3%)*	*0% - 5%*

Table 5. Frequency of occurrence (freq.) and average number of individuals (avg.) per trap of the most frequent arthropods captured in cornfields adjacent to cool and warm season buffers in 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland.

| | | Pitfall | | | | Sticky | | | |
| | | Cool Season | | Warm Season | | Cool Season | | Warm Season | |
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Herbivores									
Diptera	*adults, misc.*	73.11%	3.74	58.10%	2.92	3.21%	0.03	6.54%	0.08
	Chloropidae	--	--	--	--	99.08%	20.39	96.73%	14.66
	Otitidae	--	--	--	--	78.90%	18.75	61.68%	13.79
	Cecidomyiidae	--	--	--	--	61.01%	1.50	59.35%	1.45
	Agromyzidae	--	--	--	--	1.38%	0.02	5.61%	0.11
Homoptera	Cicadellidae	3.77%	0.07	8.10%	0.14	96.79%	11.94	97.20%	13.04
	Aleyrodidae	--	--	--	--	59.63%	4.33	53.74%	4.69
	Aphididae	--	--	--	--	33.49%	1.06	41.12%	0.84
Thysanoptera	Thripidae	--	--	--	--	80.28%	7.66	80.37%	7.30
Hemiptera	Miridae	5.19%	0.07	7.62%	0.47	33.03%	1.41	34.11%	0.96
Stylommatophora		40.09%	1.07	25.71%	0.90	--	--	--	--
Coleoptera	Chrysomelidae	5.19%	0.07	7.14%	0.13	27.52%	0.67	32.71%	0.95
	Scarabaeidae	18.40%	0.66	15.71%	0.34	--	--	--	--
	Elateridae	8.50%	12.26	9.05%	0.10	5.96%	0.09	3.27%	0.03
Orthoptera	Tettigonidae	--	--	--	--	13.76%	0.24	9.35%	0.17
	Acrididae	--	--	--	--	6.42%	0.09	1.40%	0.02
Lepidoptera	*adults, misc.*	--	--	--	--	7.34%	0.09	10.28%	0.20
	larvae, misc.	--	--	--	--	10.09%	0.12	4.21%	0.05
Predators									
Araneida		73.58%	5.27	80.48%	6.70	56.88%	1.09	54.21%	0.82
Coleoptera	Carabidae	70.28%	4.92	73.81%	5.13	4.13%	0.04	4.67%	0.05
	Staphylinidae	45.75%	3.63	48.10%	2.62	12.84%	0.15	17.76%	0.24
	Coccinellidae	6.13%	0.08	5.24%	0.05	48.62%	1.01	30.37%	0.42
	Lampyridae	--	--	--	--	5.96%	0.07	4.67%	0.13
Diptera	Ceratopongonidae	--	--	--	--	58.26%	2.69	48.60%	1.70
	Dolichopodidae	--	--	--	--	36.70%	0.75	37.85%	1.08
	Syrphidae	--	--	--	--	27.06%	2.07	14.02%	0.52
Hemiptera	Anthocoridae	--	--	--	--	42.66%	1.33	48.60%	1.21
Hymenoptera	Formicidae	34.91%	1.22	36.19%	1.74	--	--	--	--
Chilopoda		29.72%	0.71	22.86%	0.59	--	--	--	--
Phalangida		15.57%	0.34	10.95%	0.21	--	--	--	--

Table 5 continued.

| | | Pitfall | | | | Sticky | | | |
| | | Cool Season | | Warm Season | | Cool Season | | Warm Season | |
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Saprovores									
Collembola		90.09%	54.91	89.52%	48.13	--	--	--	--
Orthoptera	Gryllidae	80.19%	60.39	77.14%	21.28	--	--	--	--
Diptera	Sciaridae	--	--	--	--	72.48%	3.47	71.50%	2.86
	Scatopsidae	--	--	--	--	24.77%	2.20	40.65%	1.45
	Chironomidae	--	--	--	--	25.69%	0.46	39.25%	1.01
	Drosophilidae	--	--	--	--	29.82%	0.84	16.82%	0.30
	Muscidae	--	--	--	--	16.51%	0.31	17.76%	0.31
	Psychodidae	--	--	--	--	25.69%	4.03	5.61%	1.39
	Mycetophilidae	--	--	--	--	6.42%	0.14	4.21%	0.08
	Tipulidae	--	--	--	--	6.42%	0.16	4.67%	0.05
Acarina		63.68%	20.92	66.19%	23.08	--	--	--	--
Coleoptera	adults, misc.	--	--	--	--	6.42%	0.08	6.07%	0.07
	Ortoperidae	--	--	--	--	57.34%	1.53	55.61%	1.70
	Phalacridae	11.32%	0.30	6.19%	0.09	47.25%	1.06	60.28%	1.48
	Nitidulidae	17.92%	0.47	14.76%	0.33	--	--	--	--
	Cryptophagidae	13.68%	0.50	15.76%	0.44	4.13%	0.04	6.54%	0.07
	Mycetophagidae	8.49%	0.16	8.10%	0.15	--	--	--	--
	Anthicidae	6.60%	0.15	6.19%	0.10	--	--	--	--
	Derodontidae	--	--	--	--	4.59%	0.05	6.07%	0.10
Pscoptera	Psocidae	--	--	--	--	30.28%	0.46	41.12%	0.74
Isopoda		32.08%	4.61	17.14%	0.68	--	--	--	--
Diplopoda		17.45%	0.32	10.48%	0.58	--	--	--	--
Parastioids									
Hymenoptera	adults, misc.	14.62%	0.23	15.24%	0.23	1.38%	0.02	3.74%	0.07
	Mymaridae	--	--	--	--	78.44%	3.38	88.79%	6.05
	Scelionidae	32.55%	1.11	35.71%	1.06	74.77%	2.38	82.71%	2.47
	Trichogrammatidae	--	--	--	--	58.26%	1.56	69.16%	4.29
	Braconidae	--	--	--	--	49.08%	1.20	26.64%	37.85
	Charipidae	--	--	--	--	35.78%	0.85	27.10%	0.40
	Cerphronidae	--	--	--	--	24.31%	0.57	26.17%	0.60
	Eulophidae	--	--	--	--	26.15%	0.72	21.03%	0.30
	Encyrtidae	--	--	--	--	12.84%	0.21	15.42%	0.27
	Diapriidae	--	--	--	--	11.47%	0.16	7.48%	0.12
	Pteromalidae	--	--	--	--	9.63%	0.16	4.21%	0.05
Diptera	Phoridae	25.47%	0.68	22.86%	0.70	69.72%	2.28	67.76%	2.10
	Calliphoridae/ Sarcophagidae/ Tachinidae	--	--	--	--	76.15%	10.29	57.48%	5.84

Table 6. Frequency of occurrence (freq.) and average number of individuals (avg.) per trap of the most frequent arthropods captured in soybean fields adjacent to cool and warm season buffers in 2004 in Caroline, Talbot, and Queen Anne's Counties.

		Pitfall				Sticky			
		Cool Season		Warm Season		Cool Season		Warm Season	
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Herbivores									
Homoptera	Cicadellidae	6.17%	0.07	5.32%	0.07	100.00%	23.52	99.07%	22.63
	Aleyrodidae	--	--	--	--	94.05%	55.70	83.33%	30.59
	Aphididae	--	--	--	--	82.14%	11.85	88.89%	6.31
	Cercopidae	--	--	--	--	10.71%	0.21	9.26%	0.12
	Psyllidae	--	--	--	--	9.52%	0.11	5.56%	0.06
	Membracidae	--	--	--	--	10.71%	0.19	4.63%	0.06
Thysanoptera	Thripidae	6.17%	0.65	7.45%	0.88	100.00%	147.10	96.30%	90.65
Diptera	*adults, misc.*	80.25%	5.37	75.53%	3.91	7.14%	0.17	9.26%	0.21
	larvae, misc.	6.17%	0.44	3.19%	0.09	--	--	--	--
	Chloropidae	--	--	--	--	96.43%	47.17	97.22%	39.31
	Cecidomyiidae	--	--	--	--	54.76%	1.11	49.07%	1.11
	Otitidae	--	--	--	--	38.10%	0.79	43.52%	1.05
	Agromyzidae	--	--	--	--	17.86%	0.73	12.04%	0.44
	Tephritidae	--	--	--	--	7.14%	0.08	1.85%	0.02
Hemiptera	Miridae	7.41%	2.84	9.57%	0.12	44.05%	0.89	58.33%	2.11
Lepidoptera	*adults, misc.*	--	--	--	--	53.57%	0.94	46.30%	0.86
	larvae, misc.	12.35%	0.15	14.89%	0.18	--	--	--	--
Coleoptera	Scarabaeidae	24.69%	0.46	29.79%	0.61	--	--	--	--
	Elateridae	17.28%	0.32	23.40%	0.33	8.33%	0.10	7.41%	0.12
	Chrysomelidae	7.41%	0.07	10.64%	0.17	7.14%	0.08	19.44%	0.25
	Curculionidae	--	--	--	--	--	--	--	--
	Mordellidae	--	--	--	--	16.67%	0.19	10.19%	0.13
Stylommatophora		14.81%	0.28	21.28%	0.36	--	--	--	--
Orthoptera	Tettigoniidae	--	--	--	--	27.38%	0.60	8.33%	0.14
	Acrididae	8.64%	0.12	8.51%	0.13	8.33%	0.10	19.44%	0.25
Hymenoptera	Apiodea	--	--	--	--	5.95%	0.10	7.41%	0.11
Predators									
Araneida		93.83%	12.54	90.43%	6.28	71.43%	1.73	62.04%	1.24
Coleoptera	Carabidae	93.83%	12.90	81.91%	5.12	4.76%	0.06	9.26%	0.10
	Staphylinidae	39.51%	1.94	60.64%	2.59	29.76%	0.42	21.30%	0.26
	Chrysomelidae	--	--	--	--	15.48%	0.21	25.93%	0.32
	Lampyridae	--	--	--	--	16.67%	0.26	9.26%	0.29
	Cantharidae	0.00%	0.00	6.38%	0.19	--	--	--	--
Diptera	Dolichopodidae	--	--	--	--	55.95%	2.58	49.07%	2.62
	Ceratopogonidae	--	--	--	--	41.67%	0.89	25.00%	0.47
	Syrphidae	--	--	--	--	15.48%	0.60	21.30%	0.30
Hymenoptera	Formicidae	30.86%	1.09	45.74%	1.86	--	--	--	--
Hemiptera	Anthocoridae	--	--	--	--	36.90%	0.54	37.96%	0.76
	Pentatomidae	11.11%	0.23	15.96%	0.22	--	--	--	--
	Corimelaenidae	1.23%	0.02	17.02%	0.44	2.38%	0.06	16.67%	0.34
Chilopoda		25.93%	0.53	25.53%	0.48	--	--	--	--
Phalangida		24.69%	0.64	20.21%	0.27	--	--	--	--

Table 6 continued.

| | | Pitfall | | | | Sticky | | | |
| | | Cool Season | | Warm Season | | Cool Season | | Warm Season | |
		freq.	avg.	freq.	avg.	freq.	avg.	freq.	avg.
Saprovores									
Orthoptera	Gryllidae	98.77%	46.15	97.87%	55.27	--	--	--	--
Collembola		93.83%	35.90	88.30%	36.27	--	--	--	--
Diptera	Sciaridae	--	--	--	--	80.95%	3.88	71.30%	3.06
	Scatopsidae	--	--	--	--	58.33%	4.37	64.81%	3.57
	Chironomidae	--	--	--	--	33.33%	0.89	35.19%	0.95
	Muscidae	--	--	--	--	27.38%	0.90	27.78%	1.46
	Drosophilidae	--	--	--	--	2.38%	0.27	9.26%	0.19
	Sphaeroceridae	--	--	--	--	21.43%	0.32	6.48%	0.07
	Mycetophilidae	--	--	--	--	8.33%	0.12	9.26%	0.17
	Psycodidae	--	--	--	--	3.57%	0.04	6.48%	0.07
Acarina		72.84%	6.26	74.47%	25.98	--	--	--	--
Coleoptera	*adults, misc.*	4.94%	0.05	0.00%	0.00	10.71%	0.12	3.70%	0.05
	larvae, misc.	1.23%	0.01	3.19%	0.03	--	--	--	--
	Orthoperidae	--	--	--	--	45.24%	1.74	28.70%	0.69
	Phalacridae	--	--	--	--	17.86%	0.23	17.59%	0.19
	Cryptophagidae	16.05%	0.17	9.57%	0.21	11.90%	0.13	11.11%	0.13
	Derodontidae	--	--	--	--	6.52%	0.10	#######	0.16
	Oedemeridae	4.94%	0.05	2.13%	0.02	9.52%	0.13	6.48%	0.08
	Mycetophagidae	2.47%	0.02	11.70%	0.18	--	--	--	--
	Anthicidae	4.94%	0.06	8.51%	0.16	--	--	--	--
Isopoda		35.80%	3.98	31.91%	2.06	--	--	--	--
Psocoptera	Psocidae	--	--	--	--	29.76%	0.49	16.67%	0.21
Diplopoda		11.11%	0.43	38.30%	2.36	--	--	--	--
Parastioids									
Hymenoptera	*adults, misc.*	18.52%	0.43	9.57%	0.16	3.57%	0.04	2.78%	0.06
	Scelionidae	45.68%	1.68	52.13%	1.31	85.71%	2.94	87.96%	3.70
	Mymaridae	--	--	--	--	82.14%	3.39	87.96%	3.61
	Trichogrammatidae	--	--	--	--	65.48%	3.06	63.89%	1.81
	Ceraphronidae	--	--	--	--	30.95%	0.48	34.26%	0.53
	Braconidae	--	--	--	--	30.95%	0.39	34.26%	0.45
	Encyrtidae	--	--	--	--	39.29%	0.76	25.93%	0.44
	Eulophidae	--	--	--	--	22.62%	0.36	24.07%	0.31
	Diapriidae	--	--	--	--	11.90%	0.14	18.52%	0.20
	Charipidae	--	--	--	--	17.86%	0.21	12.04%	0.14
	Aphelinidae	--	--	--	--	11.90%	0.20	3.70%	0.04
	Chalcididae	--	--	--	--	2.38%	0.02	6.48%	0.06
Diptera	Calliphoridae/	--	--	--	--	39.29%	1.52	63.89%	3.14
	Phoridae	28.40%	0.78	20.21%	0.49	58.33%	1.20	47.22%	1.51
	Bethylidae	--	--	--	--	7.14%	0.11	2.78%	0.06
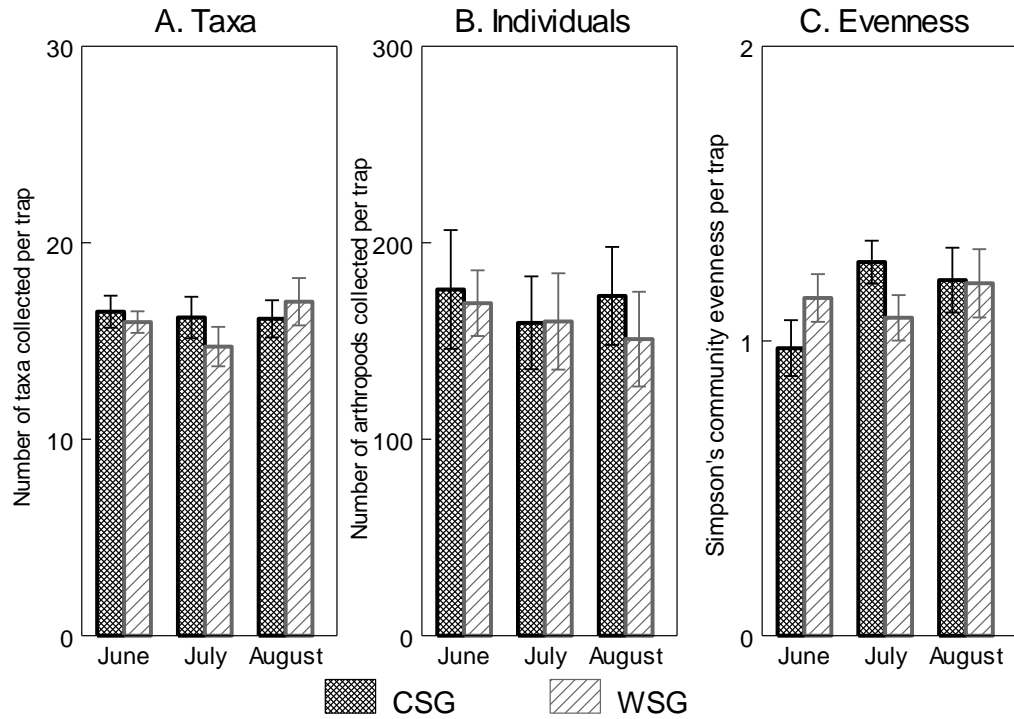
Figure 1. Community structure and diversity properties of epigeal arthropods in riparian buffers of cool season grasses and warm season grasses. There were no significant effects of buffer type or sampling month. Data are based on pitfall trap catches pooled over 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland.
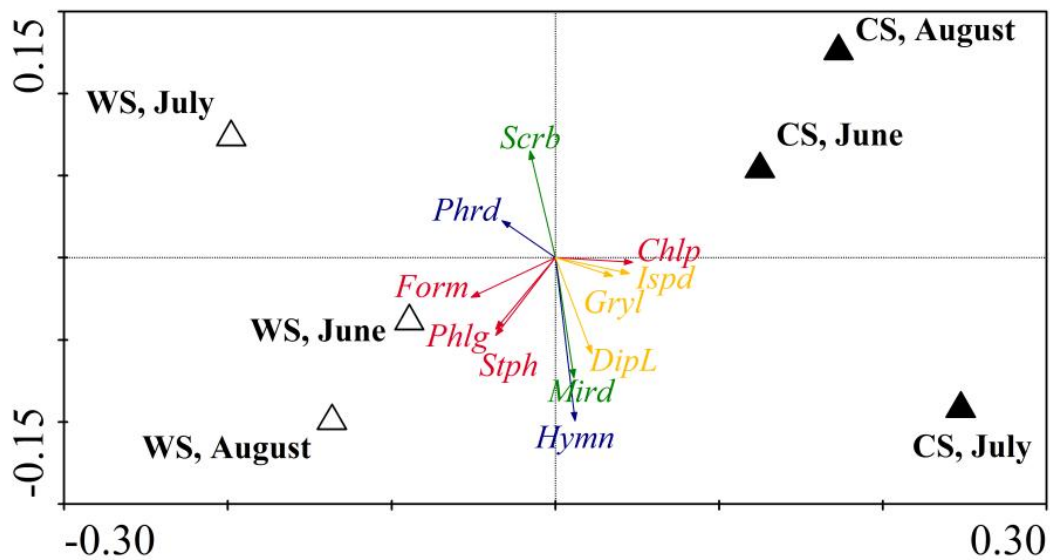
Herbivores	
Mird	Miridae
Scrb	Scarabaeidae
Saprovores	
DipL	Diptera Larvae
Gryl	Gryllidae
Ispd	Isopoda
Predators	
Chlp	Chilopoda
Form	Formicidae
Phlg	Phalangida
Stph	Staphylinidae
Parasitoids	
Hymn	Hymenoptera
Phrd	Phoridae

Figure 2. Redundancy analysis (RDA) biplot illustrating the relationship between explanatory variables (grass type and sampling month) and composition of taxa in epigeal communities in cool (CS) and warm season (WS) grass buffers from 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland. The biplot presents only those taxa that passed the inclusion rule of a 3–100% fit range. The first and second ordination axes explained 4.1% of the variation in the epigeal taxa data and 88.2% of the fitted data due to the explanatory variables.
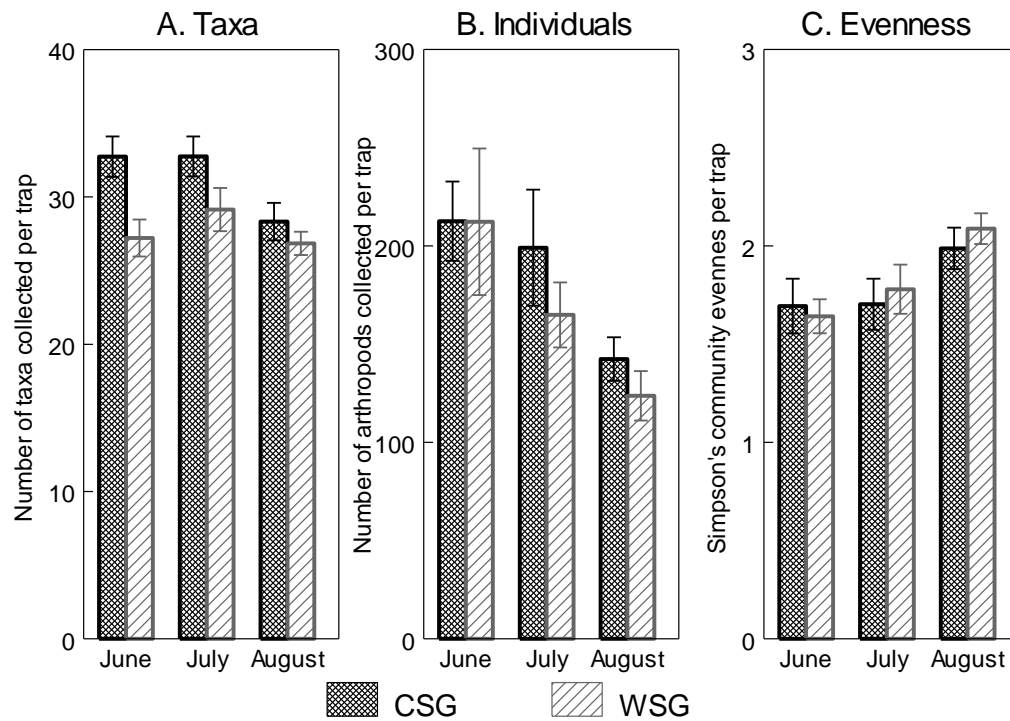
Figure 3. Community structure and diversity properties of canopy-dwelling arthropods in riparian buffers of cool season grasses and warm season grasses in Caroline, Talbot, and Queen Anne's Counties in Maryland in 2003 and 2004. The number of taxa captured (A) was significantly affected by both buffer type ($F_{(1,106)} = 16.02$, $P < 0.01$) and sampling month ($F_{(2,106)} = 5.05$, $P < 0.01$). The total number of individuals collected in each buffer (B) was not significantly affected by buffer type ($F_{(1,106)} = 1.6$, $P = 0.21$), but significantly affected by sampling month ($F_{(2,106)} = 12.49$, $P < 0.01$). Community evenness in each buffer was also not significantly affected by buffer type ($F_{(1,106)} = 0.07$, $P = 0.79$), but significantly affected by sampling month ($F_{(2,106)} = 13.49$, $P < 0.01$).
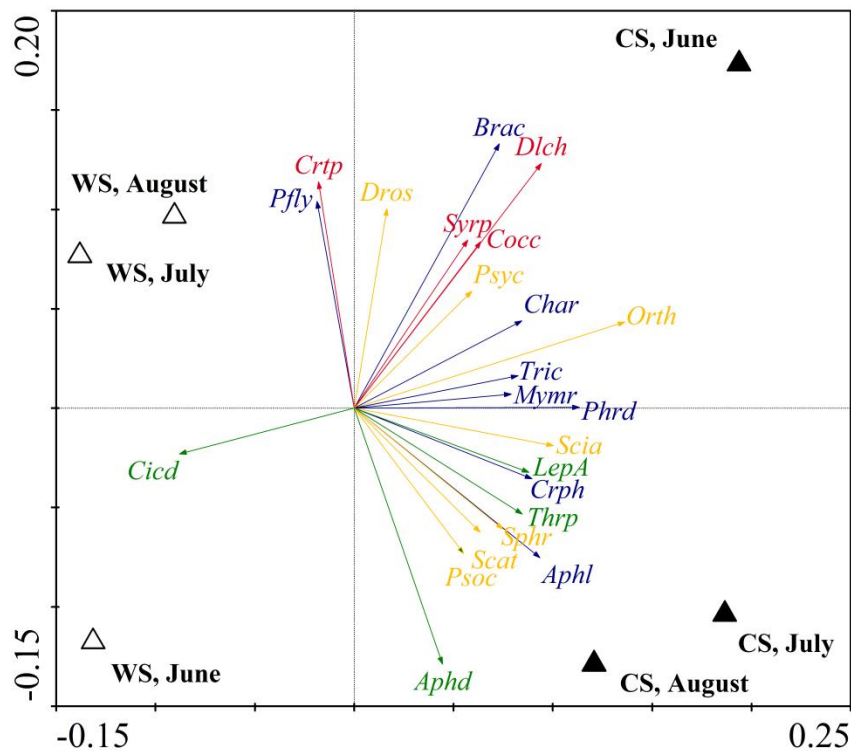
Herbivores

Aphd	Aphididae
Cicd	Cicadellidae
LepA	Lepidoptera Adult
Thrp	Thripidae

Saprovores

Dros	Drosophilidae
Orth	Orthoperidae
Psoc	Psocidae
Psyc	Psychodidae
Scat	Scatopsidae
Scia	Sciaridae
Sphr	Sphaeroceridae

Predators

Cocc	Coccinellidae
Crtp	Ceratopogonidae
Dlch	Dolichopodidae
Syrp	Syrphidae

Parasitoids

Aphl	Aphelinidae
Brac	Braconidae
Char	Charipidae
Crph	Ceraphronidae
Mymr	Mymaridae
Pfly	Calliphoridae, Sarcophagidae, Tachinidae
Phrd	Phoridae
Tric	Trichogrammatidae

Figure 4. Redundancy analysis (RDA) biplot illustrating the relationship between explanatory variables (grass type and sampling month) and composition of taxa in aerial communities in riparian grass buffers from 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland. After assigning year and adjacent crop as covariables, the first two axes explained 4.9% of the variation in the aerial taxa data and 91.8% of the fitted species data due to the interaction between sampling month and buffer type. Warm season grass buffers (WS) were clearly and significantly separated from cool season grass buffers (CS) (499 Monte Carlo permutations, $P < 0.01$).
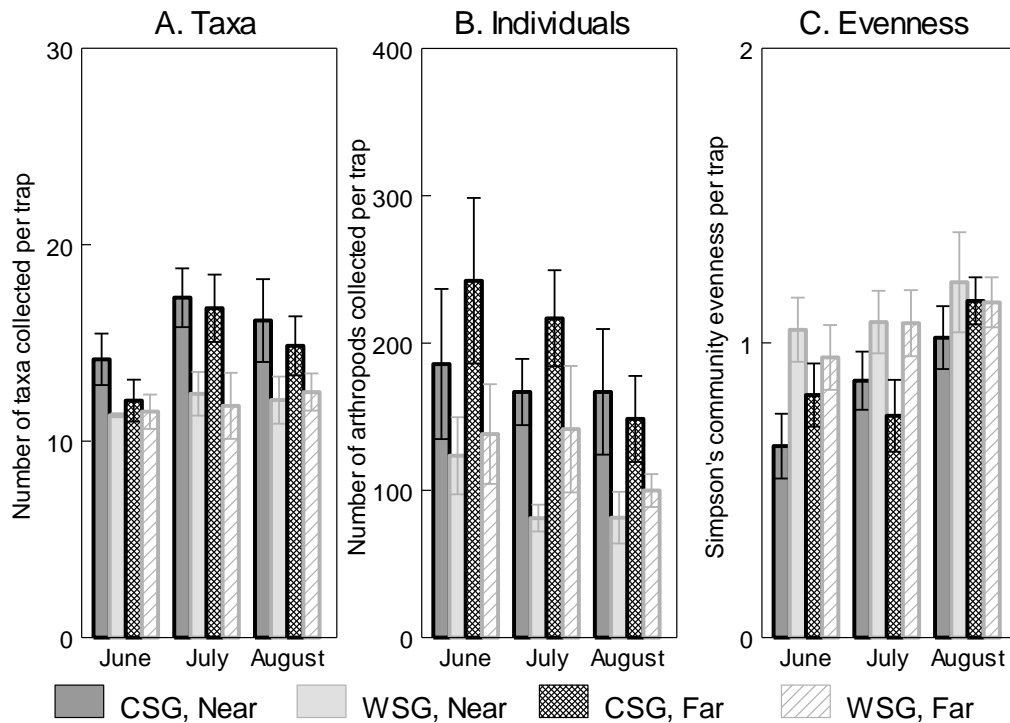
Figure 5. Community structure and diversity properties of epigeal arthropods in cornfields adjacent to cool season grass (CSG) and warm season grass (WSG) buffers in Caroline, Talbot, and Queen Anne's Counties in Maryland from 2003 and 2004. The number of taxa captured per sampling site in each field (A) was not significantly affected by adjacent buffer type ($F_{(1,132)} = 0.12$; $P = 0.73$), but was significantly affected by sampling month ($F_{(2,132)} = 6.52$; $P < 0.01$). The number of taxa collected at the two sampling sites within the field, near and far, were not significantly different ($F_{(1,132)} = 0.71$; $P = 0.40$). The number of individuals collected in each buffer (B) was significantly affected by buffer type ($F_{(1,132)} = 12.27$, $P < 0.01$), but was not significantly affected by sampling month ($F_{(2,132)} = 1.56$, $P = 0.21$) or sampling site ($F_{(1,132)} = 1.18$, $P = 0.28$). Community evenness in each buffer was significantly affected by both buffer type ($F_{(1,132)} = 6.05$, $P = 0.02$), and sampling month ($F_{(1,132)} = 4.10$; $P = 0.02$), but was not significantly affected by sampling site ($F_{(1,132)} = 0.00$, $P = 0.95$).
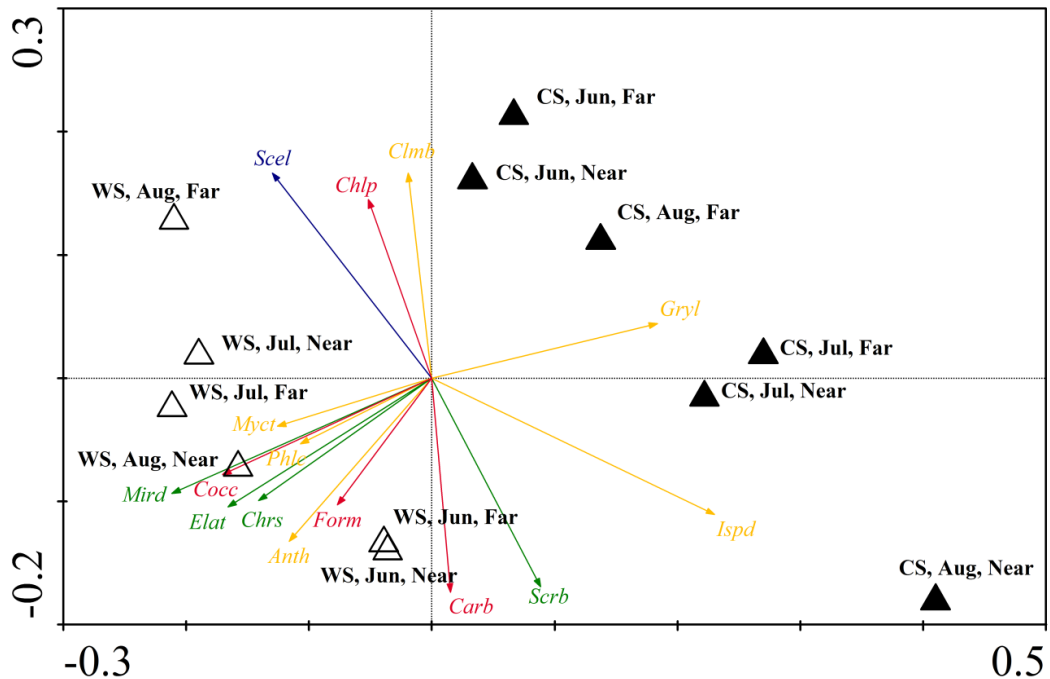
Herbivores

Chrs	Chrysomelidae
Elat	Elateridae
Mird	Miridae
Scrb	Scarabaeidae

Saprovores

Anth	Anthicidae
Clmb	Collembola
Gryl	Gryllidae
Ispd	Isopoda
Myct	Mycetophagidae
Phlc	Phalacridae

Predators

Carb	Carabidae
Chlp	Chilopoda
Cocc	Coccinellidae
Form	Formicidae

Parasitoids

Scel	Scelionidae

Figure 6. Redundancy analysis (RDA) biplot illustrating the relationship between explanatory variables (adjacent grass buffer type, sampling month, and sampling site) and composition of taxa of epigeal arthropods collected in pitfall traps in cornfields in 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties in Maryland. After assigning year and sampling month as covariables, the first two axes explained 6.1% of the variation in the taxa data and 69.0% of the fitted taxa data due to the explanatory variables. The overall community response was significantly related to the explanatory variables (499 Monte Carlo permutations, $P < 0.01$).
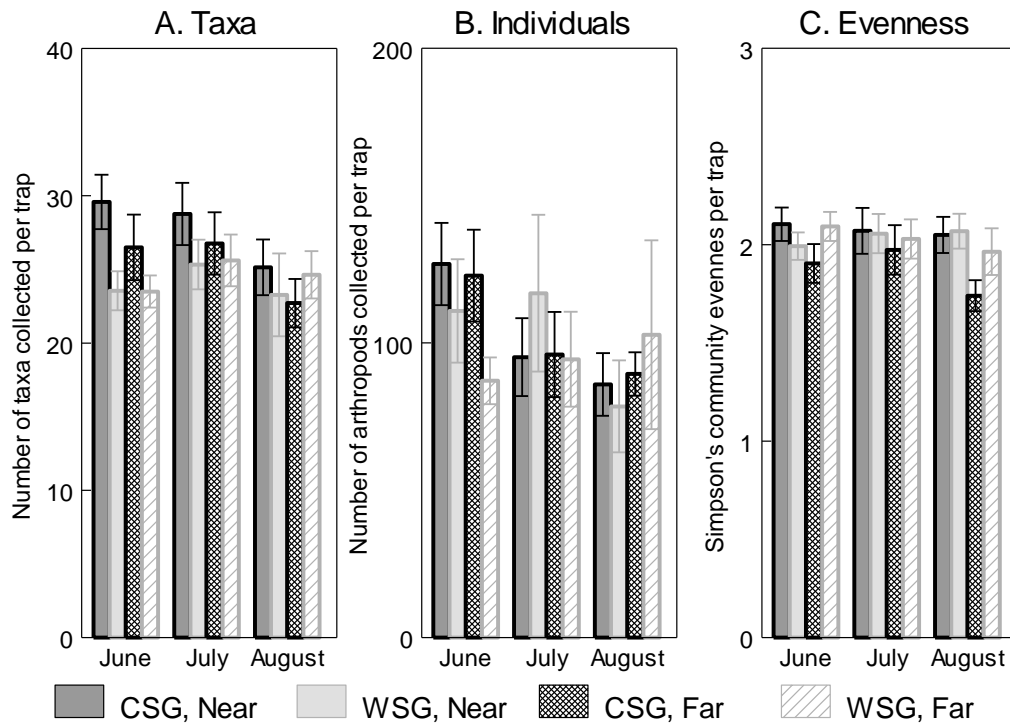
Figure 7. Community structure and diversity properties of aerially active arthropods in cornfields adjacent to cool season grass (CSG) and warm season grass (WSG) buffers in 2003 and 2004 in Caroline, Talbot, and Queen Anne's Counties. The number of taxa captured per sampling site in each field (A) was not significantly affected by adjacent buffer type ($F_{(1,129)}$ = 0.27, P = 0.60), by sampling month ($F_{(2,129)}$ = 0.94, P = 0.39), or by sampling site (near or far; $F_{(1,129)}$ = 1.05, P = 0.31). The number of individuals collected in each buffer (B) was not significantly affected by buffer type ($F_{(1,129)}$ = 1.61, P = 0.21), but was significantly affected by sampling month ($F_{(2,129)}$ = 5.21, P < 0.01). The number of individuals collected was not significantly different among sampling sites ($F_{(1,129)}$ = 0.21, P = 0.65). Community evenness in each buffer was not significantly affected by buffer type ($F_{(1,129)}$ = 0.15, P = 0.70), but was significantly affected by both sampling month ($F_{(2,129)}$ = 4.82, P < 0.01), and sampling site ($F_{(1,129)}$ = 5.83, P = 0.02).
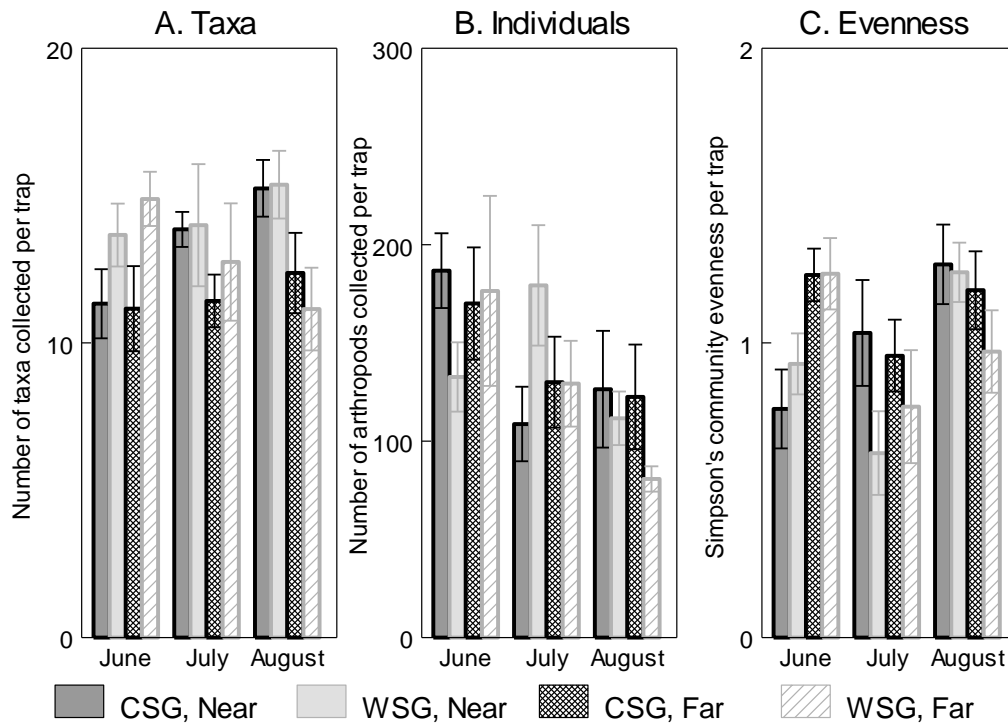
Figure 8. Community structure and diversity properties of epigeal arthropods in soybean fields adjacent to cool season grass (CSG) and warm season grass (WSG) buffers in 2004 in Caroline, Talbot, and Queen Anne's Counties. The number of taxa captured per sampling site in each field (A) was not significantly affected by adjacent buffer type ($F_{(1,71)} = 0.57$, $P = 0.45$) or by sampling month ($F_{(2,71)} = 0.44$, $P = 0.64$), but was significantly affected by sampling site ($F_{(1,71)} = 4.60$, $P = 0.04$). The number of individuals collected in each buffer (B) was not significantly affected by buffer type ($F_{(1,71)} = 0$, $P = 0.97$), but was significantly affected by sampling month ($F_{(2,71)} = 5.39$, $P < 0.01$). The number of individuals collected was not significantly different among sampling sites ($F_{(1,71)} = 0.28$, $P = 0.60$). Community evenness in each buffer was significantly affected by the interaction effect of buffer type and sampling month ($F_{(2,71)} = 3.18$, $P = 0.05$), as well as the main effects of both buffer type ($F_{(1,71)} = 9.12$, $P < 0.01$) and sampling month ($F_{(2,71)} = 6.98$, $P < 0.01$). The interaction effect of sampling month and sampling site was also significant ($F_{(2,71)} = 7.72$, $P < 0.01$), but the main effect of sampling site was not significant ($F_{(1,71)} = 1.23$, $P = 0.27$).
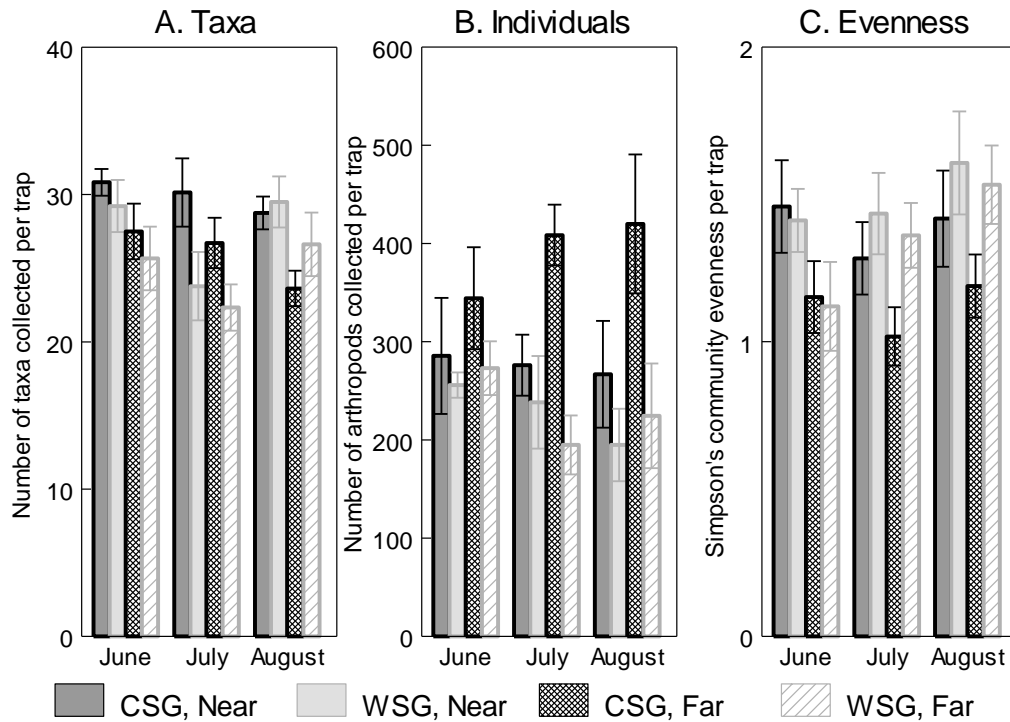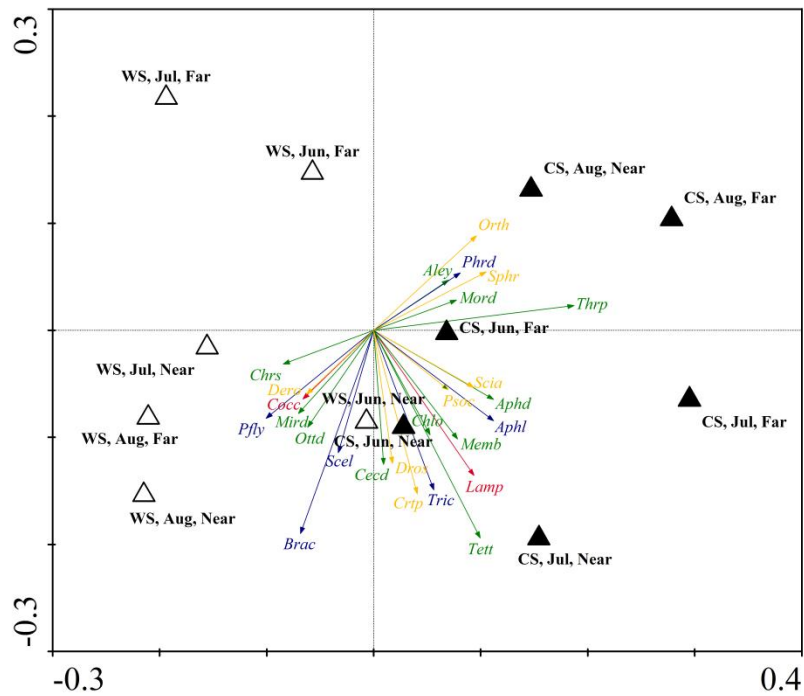
Figure 9. Community structure and diversity properties of aerially active arthropods in soybean fields adjacent to cool season grass (CSG) and warm season grass (WSG) buffers in 2004 in Caroline, Talbot, and Queen Anne's Counties. The number of taxa captured per sampling site in each field (A) was not significantly affected by adjacent buffer type ($F_{(1,76)} = 0.29$, $P = 0.59$) or by sampling month ($F_{(2,76)} = 2.19$, $P = 0.12$), but was significantly affected by the interaction between the two ($F_{(2,76)} = 6.19$, $P < 0.01$) Sampling site did have a significant effect on the number of taxa collected ($F_{(1,76)} = 6.19$, $P < 0.01$). The number of individuals collected in each buffer (B) was not significantly affected by buffer type ($F_{(1,76)} = 2.91$, $P = 0.09$), nor was it significantly affected by sampling month ($F_{(2,76)} = 0.06$, $P = 0.94$). The interaction effect of adjacent buffer type and sampling site was significant ($F_{(1,76)} = 7.31$, $P < 0.01$), as was the main effect of sampling site ($F_{(1,76)} = 7.61$, $P < 0.01$). Community evenness in each buffer was not significantly affected by the adjacent buffer type ($F_{(1,76)} = 0.03$, $P = 0.86$) or sampling month ($F_{(2,76)} = 2.97$, $P = 0.06$). Community evenness was significantly affected by sampling site ($F_{(1,76)} = 9.55$, $P < 0.01$).

Figure 10. Redundancy analysis (RDA) biplot illustrating the relationship between explanatory variables (adjacent grass buffer type, sampling month, and sampling site) and composition of taxa of aerially active arthropods collected on sticky cards in soybean fields in 2004 in Caroline, Talbot, and Queen Anne's Counties. After assigning year and sampling month as covariables, the first two axes explained 6.9% of the variation in the taxa data and 53.7% of the fitted taxa data due to the explanatory variables. The Monte Carlo permutation test were near significant for the first axis (499 permutations, $P = 0.06$).

Herbivores

Aley	Aleyrodidae
Aphd	Aphididae
Cecd	Cecidomyiidae
Chlo	Chloropidae
Chrs	Chrysomelidae
Memb	Membracidae
Mird	Miridae
Mord	Mordellidae
Ottd	Otitidae
Tett	Tettigonidae
Thrp	Thripidae

Saprovores

Crtp	Ceratopogonidae
Dero	Derodontidae
Dros	Drosophilidae
Orth	Orthoperidae
Psoc	Psocidae
Scia	Sciaridae
Sphr	Sphaeroceridae

Predators

Cocc	Coccinellidae
Lamp	Lampyridae

Parasitoids

Aphl	Aphelinidae
Brac	Braconidae
Pfly	Calliphoridae, Sarcophagidae, Tachinidae
Phrd	Phoridae
Scel	Scelionidae
Tric	Trichogrammatidae

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