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RESEARCH ARTICLE

Assessment of arthropod diversity patterns in maize fields bordered by diverse cultivated refuge strips

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The simplification of landscapes associated with monocrop agriculture reduces the availability of habitats for beneficial arthropods that provide essential ecosystem services. Arthropod diversity can be increased through landscape enhancement, e.g. the cultivation of refuge strips (CRS). The aim of this pilot study was to investigate the effect of CRS, which is a novel management strategy in South Africa, on arthropod diversity in maize fields. Arthropod diversity and species composition was assessed along a transect from within CRS into two maize fields. The study was conducted on a large-scale commercial maize farm in the North-West province of South Africa. Two sampling methods were used (pitfall and pan traps). Traps were placed along three transects in each maize field during the pre-flowering and flowering stages of the maize crop. Each transect consisted of traps at the following distances: 0 m (within CRS), 5 m, 10 m and 20 m into the maize fields. A total of 270 pitfall and 270 pan trap samples were collected during this study. All arthropods were identified to morpho-species level and counted after which the Shannon-Wiener diversity (*H'*), Pielou's evenness (*J'*) and Margalef's diversity (*d*) were calculated. A total of 20 134 arthropods of 283 morpho-species were collected. Epigeal and flying arthropod diversity decreased as distance increased from the CRS. This trend was mirrored by the Pielou's evenness index for epigeal arthropods while the evenness of flying arthropods indicated no clear pattern. Distinct arthropod communities were present within the CRS and the maize field. This pilot study indicates that the CRS supported a diverse arthropod community during the flowering stages of maize. However, as distance from the CRS increased, arthropod diversity decreased. Further studies should be conducted to determine the diversity within refuges and maize fields throughout the cropping season, as well as at longer distances away from refuges.

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INTRODUCTION

Arthropod diversity in agroecosystems is largely influenced by the prevailing management practices (del-Val et al. 2021), scale of the agricultural land use (Sohlström et al. 2022) and heterogeneity of the system (Martínez et al. 2015). Changes in land use types across agricultural mosaics can result in changes in both the population dynamics and diversity of arthropods, especially when changes are made to refuges such as natural or non-crop habitats.

Non-crop habitats can be altered to serve as arthropod refuges, for example, through the cultivation of field margins or alley cropping, or simply though the inclusion of field margins, hedgerows, fallow fields or cultivated refuge strips (CRS) within the crop habitat. These landscape elements favour arthropod taxa and serve as corridors which increase the connectivity within the mosaic (Blaix and Moonen 2020). Refuges may also serve as overwintering habitats (Pfiffner and Luka 2000), provide microclimates favourable to various taxa (Marshall, 2004), and provide additional sources of nutrients when plants with extra floral nectar are incorporated (Ndakidemi et al. 2022). The introduction of CRS with high plant species richness adjacent to or within crop fields contribute to the hosting and subsequent dispersal of arthropods into adjacent crop fields (Wang et al. 2022). Additionally, CRS increase landscape complexity through the incorporation of a wide diversity of plants with their functional traits (Henckel et al. 2015). This enrichment of field margins with plant species may not only increase arthropod diversity within the margin but also in adjacent areas (Wang et al. 2022). Concurrently, the dispersal of epigeal and flying arthropods into the arable land could, in turn, also allow for their ecosystem services to benefit the agricultural land.

Even though much research has been conducted in Europe, the USA and the UK, limited information exists on the effects of field margins on arthropod diversity and dispersal in African maize agroecosystems. Maize is the most important crop in South Africa and is cultivated on a commercial scale across 2-3 million hectares annually (Van den Berg and du Plessis 2024). Botha et al. (2015) and Greyvenstein et al. (2020) indicated that plant and arthropod diversity within uncultivated field edges were significantly higher than within maize fields and that large numbers of beneficial arthropods occurred in these uncultivated field edges.

Arthropod diversity in maize fields in South Africa is generally considered high. For example, Botha et al. (2015; 2016) recorded 557 and 576 plant-dwelling arthropod species in maize fields compared to 373 plant-dwelling species in soybean fields (Janse van Rensburg et al. 2020). In European countries, arthropod diversity in maize fields is better described and are provided in publicly available databases. For example, Meissle et al (2013) reported that 1679 arthropod species occurred in maize in Europe.

In this study we investigated the diversity and species composition of epigeal and flying arthropods in CRS and adjacent maize fields. Information on arthropod diversity patterns in maize agroecosystems and the possible role that CRS can play as a component of conservation biocontrol will contribute to the development of improved pest management practices in large-scale maize farming systems.

The specific aim of this pilot study was to assess the diversity and spatial dispersal patterns of epigeal and flying arthropods in a maize field and adjacent refuge strips.

MATERIALS AND METHODS

Study area

The study was conducted on an 80 ha maize field on a large-scale commercial farm (-26.638276, 26.833444) in the North-West province of South Africa, during the summer months (February–April) of 2023. The study area is within the Highveld Grassland biome which has summer rainfall and cold dry winters, with vegetation ranging from smaller herbaceous communities to larger woody plants (Carbutt et al. 2011).

Conservation agriculture practices have been implemented for a 3-year period on the farm where the study was conducted and the CRS were established three years prior to this study. Cattle were allowed to graze on crop residues as well as the CRS after the previous harvest. Soil disturbance was limited to a disc cultivation before planting. Glyphosate was applied to control weeds prior to planting. Organic fertilizers were applied by means of a boom sprayer during the cropping season. No insecticide applications were done during the preceding season or the season during which this study was conducted. A genetically modified Bt maize hybrid which expressed Cry1A.105 and Cry2Ab2 insecticidal proteins for the control of lepidopterous stem borers was planted.

Experimental setup

CRS (5 m wide) were spaced at 300 m intervals across the 80-ha maize field (Figure 1). The distance between natural vegetation that surrounded the maize fields and the traps within the field ranged from 200–500 m. The CRS contained a variety of plant species with different densities and structures (Figure 1). The seed mixture used to plant the CRS contained annual- and perennial species such as Grazing vetch (*Vicia villosa* ssp. *dasycarpa*) (Fabaceae), lucerne (*Medicago sativa*) (Fabaceae), sunhemp (*Crotalaria juncea*) (Fabaceae), dolichos (*Lablab purpureus*) (Fabaceae), cowpea (*Vigna unguiculata*) (Fabaceae), tiller radish (*Raphanus sativus*) (Brassicaceae), white mustard (*Sinapis alba*) (Brassicaceae), chicory (*Cichorium intybus*) (Asteraceae), buck wheat (*Fagopyrum esculentum*) (Polygonaceae), marigold (*Tagetes erecta*) (Asteraceae) and sweet clover (*Melilotus officinalis*) (Fabaceae).

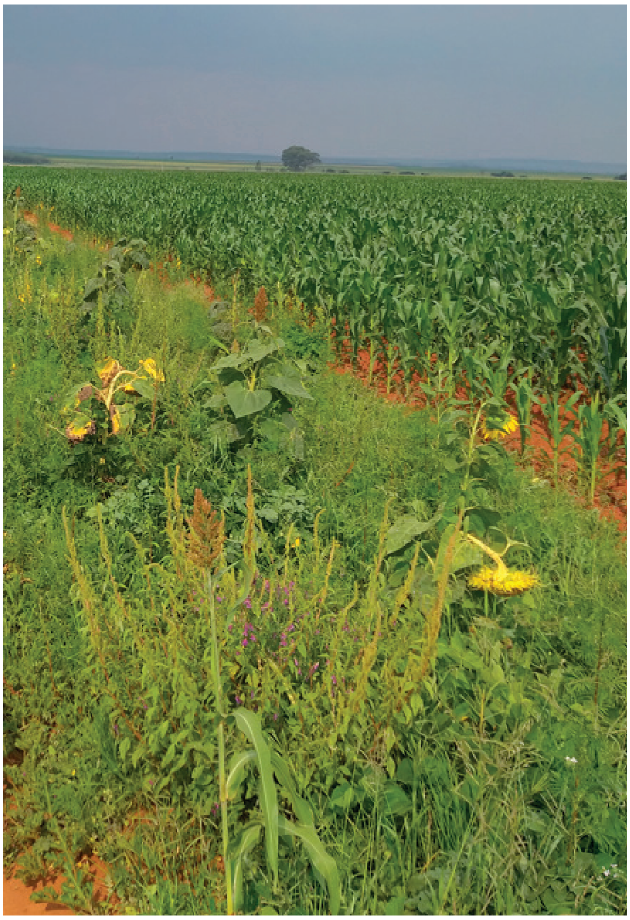

Figure 1: A cultivated refuge strip (CRS) within a maize field.

Sampling was done along three transects, at two of the CRS (Figure 2). The transects (replicates) were 100 m apart and there were five sampling stations along each transect. These sampling stations were located at the following distances along the transects: 0 m (within CRS), and 5 m, 10 m, 15 m and 20 m into the maize field (Figure 2). Three pitfall traps and three pan traps were placed at each sampling station. The pan trap at each sampling station consisted of three bowls (blue, white and yellow), each 14 cm in diameter, which was placed at a height of 1.5 m above soil surface. Honey jars (480 ml) were used as pitfall traps. The latter were filled with 70% ethanol and 10 ml of antifreeze was added to the pan traps to limit evaporation. Traps were left in the field for a 7-day period after which they were collected and transported to the Entomology Laboratory at North-West University. The contents of the traps were sorted to morpho-species level after which they identified to Order and Family level, and their abundances per trap recorded. Sampling was done for six weeks over the reproductive growth stages of the crop since this is an ideal time to sample comprehensive arthropod communities in maize (Dively, 2005; Eckert et al. 2006). Sampling commenced one week before tassel emergence and continued until the late soft-dough stage of crop development. In total, there were 270 pitfall traps, and 270 pan traps used in this study. The contents of the three pitfall traps and pan traps at each sampling station were pooled for each trapping method. Therefore, there were 90 samples per trap type that were used for statistical analyses.

Statistical analysis

PRIMER V6 software (Clarke and Gorley 2006) was used to determine the Shannon-Wiener diversity index (*H*'), Pielou's evenness index, (*J*'), Margalef's diversity index (d), Abundance (*N*) and Species richness (*S*). PRIMER V6 software (Clarke and Gorley 2006) was also used to construct species accumulation curves where the Sobs, Chao1, Chao 2, Jackknife1, Jackknife 2 and Bootstrap indices were used to determine if sampling effort was sufficient. Non-Metric Distance scaling (NMDS) graphs based on Bray-Curtis dissimilarity were constructed using the PRIMER

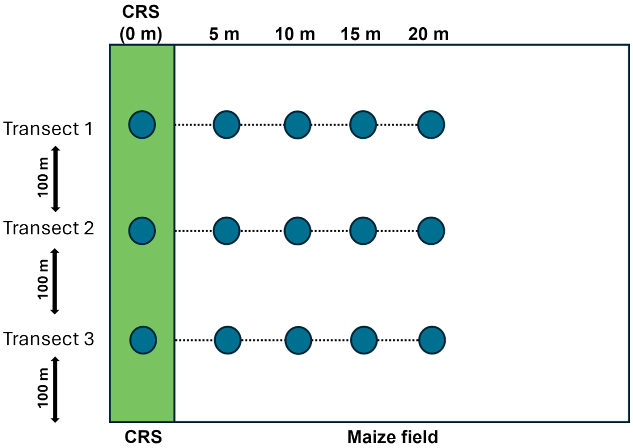

Figure 2: Layout of sampling stations across the CRS and maize field.

V6 software to depict the collected epigeal and flying arthropod communities across the different distance intervals. Furthermore, PRIMER V6 software was also used to conduct PERMANOVA analysis to determine if statistical difference in the arthropod communities existed between the CRS and different distances within the maize fields. A similarity percentage (SIMPER) analysis was conducted using PAST version 4.13 software (Hammer et al. 2001) to identify the families contributing to the dissimilarities between communities. It should be noted that due to lack of further taxonomic identification, families were used in the SIMPER analysis, with details of the numbers of morpho-species per family, displayed in the results.

The diversity index data were tested for normality with Statistica v14 software (TIBCO Software Inc. 2017), specifically with the use of the Shapiro-Wilk test. Based on the distribution of the data and the Shapiro-Wilk normality test ($p > 0.05$), either non-parametric tests (Kruskal Wallis ANOVA) or parametric tests (ANOVA) were conducted in SPSS Statistics v28 software (IBM Corporation 2021). If statistical differences were recorded between the diversity indices at the different distance intervals, non-parametric (Dunn-Bonferroni) or parametric Post-Hoc tests (Tukey HSD tests) were conducted to indicate between which of the distance intervals (0, 5, 10, 15 and 20 m), statistically significant differences occurred.

RESULTS

Descriptive results

A total of 20 134 arthropods from 15 orders, 95 families and 283 morpho-species were collected. The number of arthropods collected in pitfall traps was 13 161 while pan traps yielded 6 973 individuals. Across both trapping types 99 species were shared, 128 were distinct to the pitfall traps and 41 were collected only in pan traps. Moreover, 129 species were recorded only within the CRS, whereas 79 species occurred in both the CRS and up to 20 m into the maize field. Twenty-six species were present only at the 20 m distance. The species accumulation curves indicated that the number of pan traps used in this study provided sufficient data on flying insects to address the aims of this pilot study (Figure 3). The results indicate that more pitfall trap samples should be used in future, as the curve is depicting a slight upward trend instead of a plateau.

Coleoptera was the most diverse order (76 morpho-species), followed by the Hymenoptera (44), Diptera (41) and Hemiptera (29) (Table 1). The Coleoptera was most abundant group (5 825 individuals) in the pitfall traps, followed by the Dermaptera (2 197), Orthoptera (1 508) and Diptera (1 245). The Blattodea, Isoptera and Crustacea were the least abundant and represented by only a single morphospecies each (Table 1).

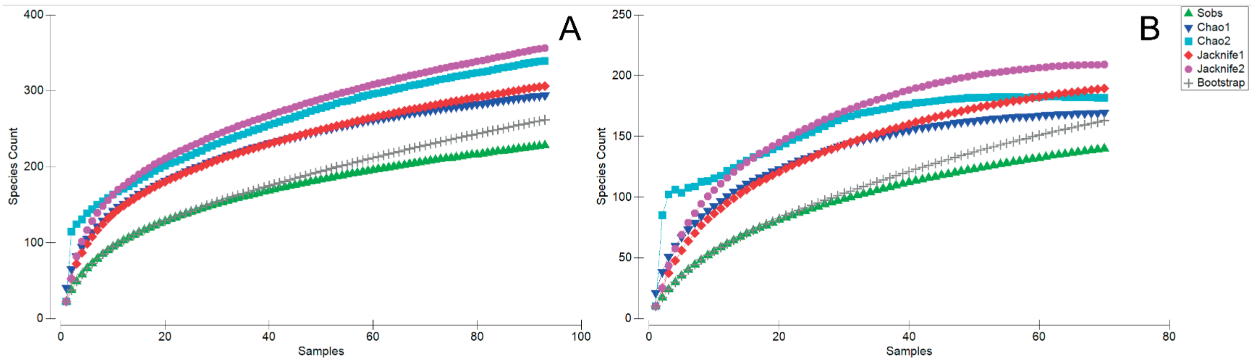

Figure 3: Species accumulation curves produced for pitfall (A) and pan (B) traps.

Table 1: Arthropod species richness and abundance recorded by means of pitfall and pan traps over a 6-week period within a maize field and an adjacent cultivated refuge strip.

	Pitfall traps		Pan traps	
Order	**Species richness**	**Abundance**	**Species richness**	**Abundance**
Coleoptera	76	5825	19	5724
Hymenoptera	44	1025	47	417
Diptera	41	1245	34	511
Hemiptera	29	811	17	206
Lepidoptera	24	63	9	31
Orthoptera	9	1508	1	5
Araneae	5	41	5	15
Diplopoda	2	390	1	1
Thysanoptera	2	4	3	55
Acari	1	7	0	0
Blattodea**	1	2	0	0
Crustacea	1	1	0	0
Dermaptera	1	2197	0	0
Isoptera	1	2	1	2
Psocoptera	1	12	1	4
Phthiraptera	0	0	1	1
Neuroptera	0	0	1	1

**It should be noted that although the order Blattodea includes the former order Isoptera, data on the latter are provided separately due to their pest status in maize.

Pan traps yielded 133 morpho-species with the Hymenoptera being the most diverse (47 morpho-species) (Table 1), followed by the Diptera (34) and Coleoptera (19). Similar to the pitfall traps, Coleoptera was also the predominant order collected in the pan traps (5 724 individuals), followed by the Diptera (511) and Hymenoptera (417) (Table 1).

Arthropod diversity along the CRS-maize field gradient

Statistically significant differences were recorded in epigeal arthropod diversity between the CRS and the various distance intervals within the maize field (Table 2; Figure 4). Pitfall data indicated that the abundance (p = 0.001), species richness (p = 0.001), Shannon-Wiener (p = 0.001) and Margalef's diversity (p = 0.001) indices were significantly lower in the maize field compared to the CRS (Table 2; Figure 4). No differences were recorded between diversity indices at any of the different distances within the maize field. Despite no statistical differences in the Pielou's evenness index-values in the main tests, the p-value was marginally non-significant (p = 0.061), therefore pairwise tests were conducted to investigate this pattern. The pairwise tests suggest possible differences (p = 0.024) between the CRS than in the maize field, however this should be investigated further in future studies due to the marginal difference in the main test. Additionally, results indicated that, with increased distance away from the CRS, there was a decrease in diversity.

For the flying insects, similar results to the epigeal arthropod data were recorded (Table 2; Figure 5). Abundance (p = 0.006), species richness (p = 0.001) and the Margalef's diversity index (p = 0.002) were significantly higher within the CRS. Shannon-Wiener diversity and Pielou's Evenness did not reflect any statistically significant differences between the CRS and maize fields. No differences were recorded in diversity at the different distance intervals in the maize field. Furthermore, Margalef's diversity and species richness were the only indices that recorded a significant difference between the CRS and the 5 m interval, which was not the case for the epigeal arthropods (Table 2; Figure 5).

Arthropod species composition along the CRS-maize field gradient

Epigeal arthropods communities indicated that distinct species assemblages were present within the CRS and maize fields, and that community composition differed significantly between these two habitats (Figure 6A). Similarly, the aerial arthropods collected by means of pan traps indicated that the CRS had a distinct arthropod community (Figure 6B) with some of those also occurring in maize.

The differences in community composition between the CRS and maize field was further supported by the PERMANOVA analysis which indicated that community composition differed significantly (p = 0.001) between the CRS and maize field for both trap types (Table 3). No differences in communities for either trap type were recorded at the different distance intervals within the maize fields (Table 3).

Table 2: Comparison of arthropod abundance, species richness and different diversity indices at different distances from a cultivated refuge strip into a maize field.

	Distances (m)	Abundance	Species richness	Shannon-Wiener diversity index	Pielou's evenness index	Margalef's diversity index
			Pitfall traps			
Main test	p-value	**<0.001***	**<0.001***	**<0.001***	0.061	**<0.001***
	F-value	17.440	44.968	12.070	2.339	40.781
Pairwise tests	20 vs.15	0.311	0.462	0.631	0.794	0.958
	20 vs. 10	0.917	0.486	0.891	0.688	0.493
	20 vs. 5	0.258	0.526	0.837	0.651	0.644
	20 vs. CRS	**<0.001***	**<0.001***	**<0.001***	0.007	**<0.001***
	15 vs. 10	0.372	0.984	0.738	0.888	0.532
	15 vs. 5	0.884	0.934	0.791	0.848	0.686
	15 vs. CRS	**<0.001***	**<0.001***	**<0.001***	0.014	**<0.001***
	10 vs. 5	0.311	0.951	0.946	0.959	0.825
	10 vs. CRS	**<0.001***	**<0.001***	**<0.001***	0.021	**<0.001***
	5 vs. CRS	**<0.001***	**<0.001***	**<0.001***	0.024	**<0.001***
			Pan traps			
Main test	p-value	**0.006***	**<0.001***	0.531	0.337	**0.002***
	F-value	3.905	8.212	0.796	1.160	4.731
Pairwise tests	20 vs.15	0.301	0.681	0.768	0.603	0.654
	20 vs. 10	0.931	0.977	0.423	0.829	0.689
	20 vs. 5	0.205	0.634	0.450	0.231	0.902
	20 vs. CRS	**0.021***	**0.004***	0.753	0.375	**0.006***
	15 vs. 10	0.241	0.645	0.580	0.459	0.972
	15 vs. 5	**0.016***	0.352	0.612	0.080	0.743
	15 vs. CRS	**<0.001***	**<0.001***	0.514	0.145	**0.015***
	10 vs. 5	0.220	0.641	0.973	0.328	0.777
	10 vs. CRS	**0.020***	**0.003***	0.239	0.509	**0.018***
	5 vs. CRS	0.305	**0.015***	0.263	0.720	**0.008***

***Indicates a** statistically significant difference at $p > 0.05$.

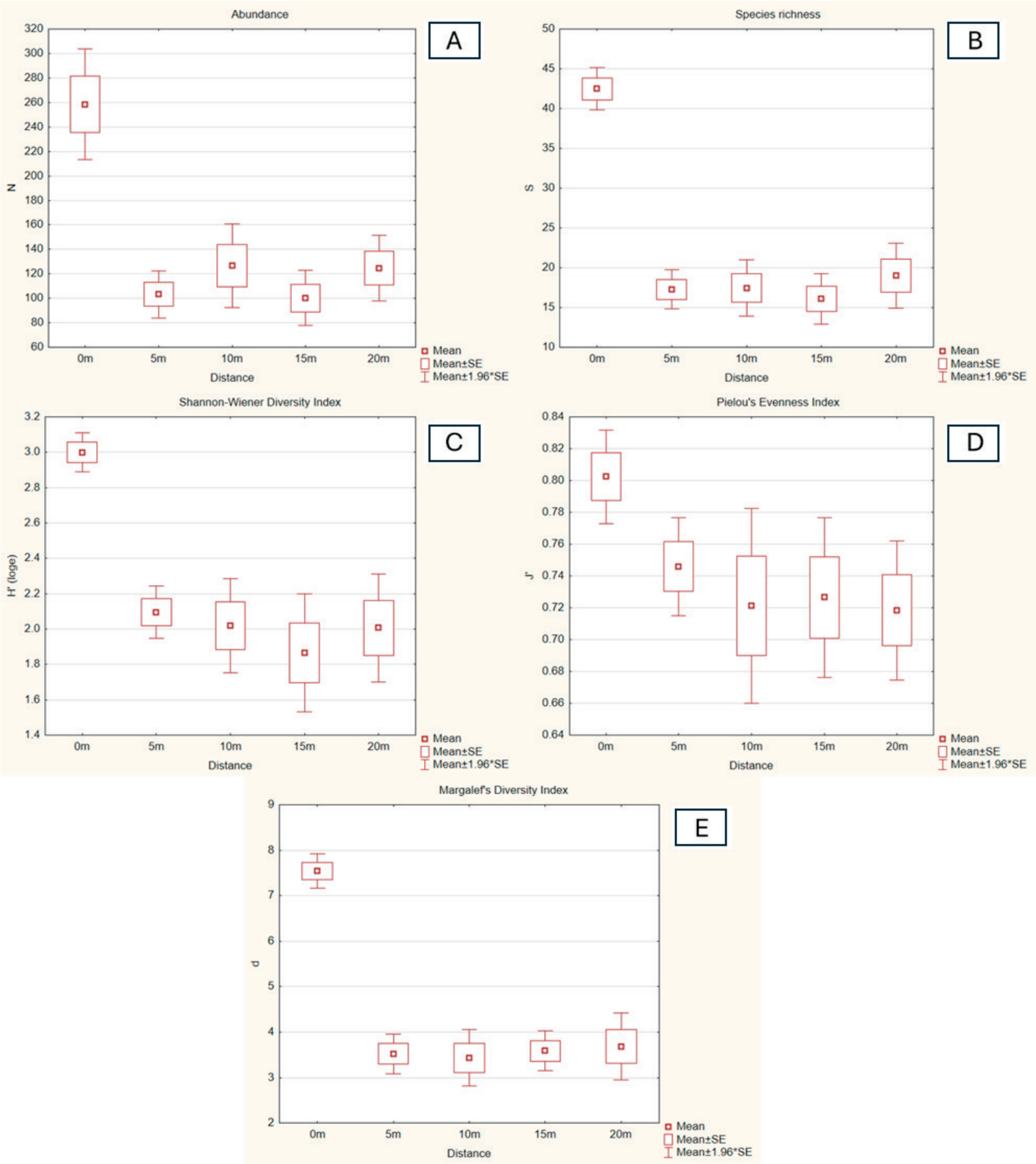

Figure 4: Mean abundance (A), species richness (B), Shannon-Wiener Diversity index (C), Pielou's evenness (D) and Margalef's diversity index (E) of arthropod communities sampled by means of pitfall traps at different distances along a transect from within the CRS into the maize field.

Arthropod families contributing to dissimilarities along the CRS-maize field gradient

As the morpho-species could not be identified beyond family level, the results of the SIMPER analysis reflect only the family and number of morpho-species per family that was associated with the dissimilarity within the maize field (different distances) and between the maize field and CRS. These results therefore summarize which arthropod families contributed most to the dissimilarity between the different distances and habitats (maize and CRS).

SIMPER analysis indicated that various families contributed to the dissimilarity in community composition at the different distances, i.e. within the CRS and within the maize field (5 m, 10 m, 15 m and 20 m) for each of the trap types (Table 4). The pitfall traps had an overall dissimilarity of 67.28%, whereas the pan traps had an overall dissimilarity of 75.11%.

The arthropods families which contributed the most to the dissimilarity in the pitfall traps within the maize field were Scarabaeidae (10.56%), Tenebrionidae (9.17%) and Carabidae (7.22%). The largest contribution to the dissimilarity between the CRS and the various distances into the maize field are attributed to the following families: Carabidae (7.22%), Tenebrionidae (5.49%) and Staphylinidae (4.68%). The maize fields and CRS hosted 18 and 13 arthropod families respectively, which cumulatively contributed to 50% of the recorded dissimilarity.

Muscidae captured in pan traps were the biggest contributor to the dissimilarity recorded at different distances within maize fields (12.81 %) as well as between maize fields and CRS (12.52%). Furthermore, high abundances of the spotted maize beetle, *Astylus atromaculatus* (Blanchard) (Coleoptera: Melyridae) were responsible for 10% and 7% dissimilarity in the maize field and between the maize field and CRS respectively. This was the only

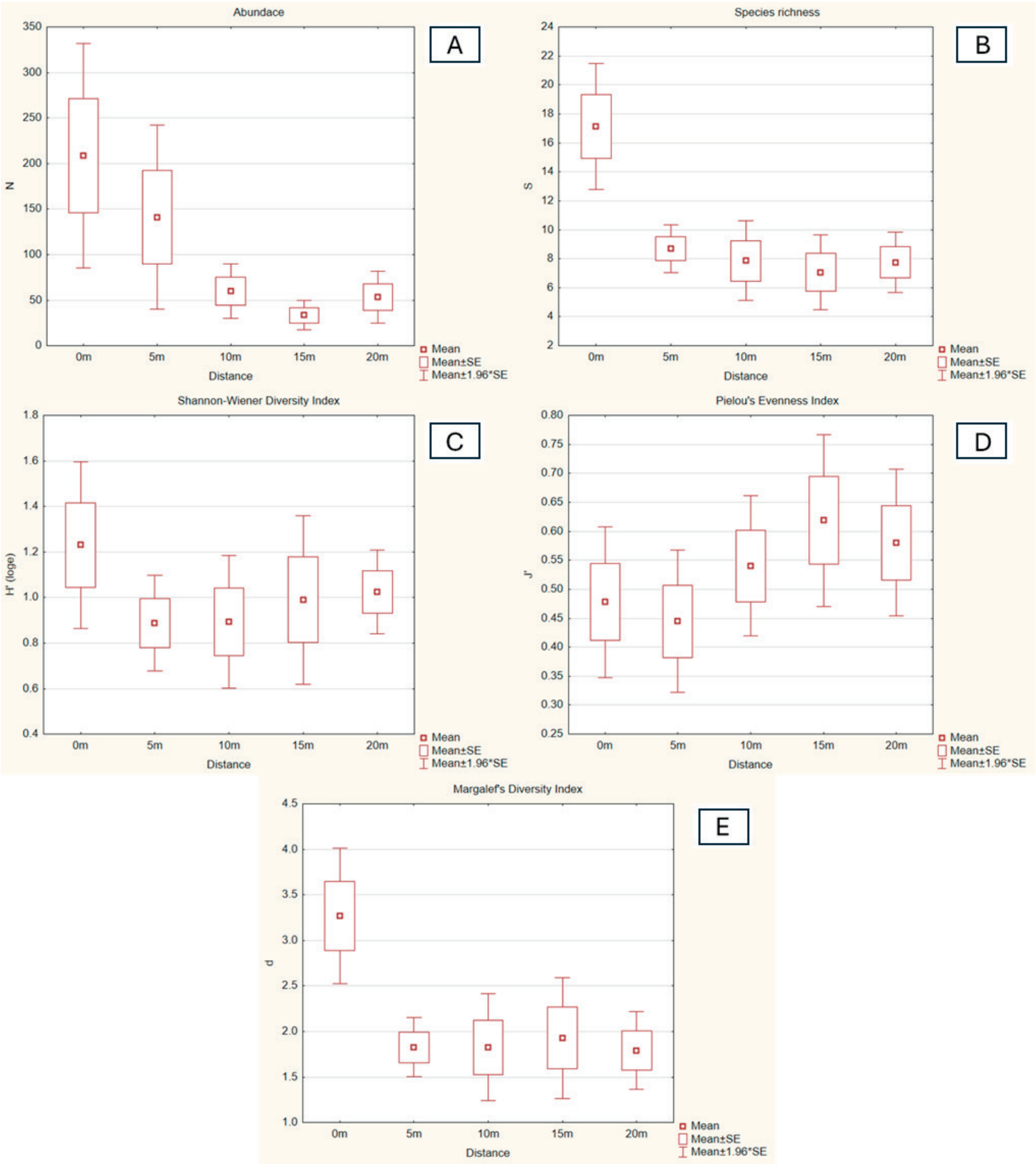

Figure 5: Mean arthropod abundance per trap (A), Species richness (B), Shannon-Wiener Diversity index (C), Pielou's evenness (D) and Margalef's diversity index (E) sampled by means of pan traps at different distances along a transect from within the CRS into the maize field.

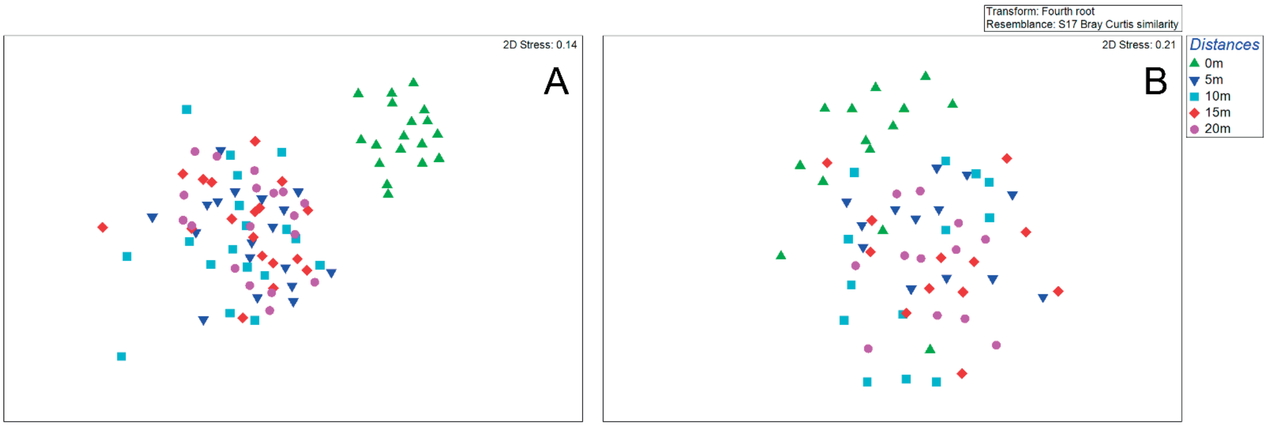

Figure 6: Non- metric distance scaling (NMDS) of epigeal and flying arthropod community composition across the cultivated refuge strip (CRS) and maize field. A) pitfall traps (epigeal arthropods), B) pan traps (flying arthropods).

Table 3: PERMANOVA results obtained after comparing the diversity of arthropods sampled by means of pitfall and pan traps in the cultivated refuge strip (0 m) and at different distances into the maize field.

Trap type	Distances (m)	*t*-value	*p*-value
Pitfall	CRS vs. 5	4.5596	**0.001***
	CRS vs. 10	4.4425	**0.001***
	CRS vs. 15	4.0708	**0.001***
	CRS vs. 20	4.2510	**0.001***
	5 vs. 10	0.7859	0.846
	5 vs. 15	1.1257	0.164
	5 vs. 20	1.0893	0.239
	10 vs. 15	0.9137	0.682
	10 vs. 20	0.9126	0.627
	15 vs. 20	0.9375	0.607
Pan	CRS vs. 5	1.8270	**0.001***
	CRS vs. 10	1.8455	**0.001***
	CRS vs. 15	1.8665	**0.001***
	CRS vs. 20	2.0138	**0.001***
	5 vs. 10	1.0769	0.273
	5 vs. 15	1.0486	0.338
	5 vs. 20	1.0492	0.361
	10 vs. 15	0.9051	0.638
	10 vs. 20	1.0231	0.370
	15 vs. 20	1.0680	0.287

*Indicates a statistically significant difference at $p < 0.05$.

Melyridae species collected during this study. Apidae was the third biggest contributor to the pan trap communities, both within the maize field and between the maize and CRS. Within the maize field, nine families contributed to 50% of the dissimilarity while 15 families were responsible for the same percentage of dissimilarity between the CRS and maize field.

DISCUSSION

The aim of this pilot study was to investigate epigeal and flying arthropod communities in CRS and maize fields. The possible benefits that CRS may provide could be of conservation biocontrol importance and contribute to the development of improved pest management practices in large-scale maize farming systems.

The species richness (283) and abundance (20 134) of arthropods collected during this six-week study at two CRS on a single farm could be considered high. Botha et al. (2015; 2016) surveyed 24 sampling sites across South Africa and recorded 576 species within maize fields, and between 1023 - 1031 species within field margins. It should, however, be noted that the sampling methods differed between this study (pitfall and pan traps) and that by Botha et al. (2015; 2016) (D-vac). The latter study showed that marginal habitats such as rangelands and field margins retain a higher diversity of arthropods in comparison to maize fields.

Distinct patterns in epigeal and aerial arthropod diversity and community composition along the CRS-maize gradient were recorded in this study. Overall, there was a decrease in diversity as distance increased from the CRS into the maize fields. This was likely due to factors such as dispersal ability, habitat preference, niche specificity as well as the differences in vegetation diversity, vegetation cover and microclimate stability which was more favourable in the CRS than in the maize field.

Jacobsen et al. (2022) indicated that a higher diversity of predatory arthropods was supported in more structurally diverse and heterogeneous field margins compared to adjacent agricultural land. The differences in community composition observed between the pitfall trap catches in maize and the CRS in this study could possibly be ascribed to the increased plant species diversity that created a wide range of habitats, in addition to providing different resources that support a wide range of species within the CRS. The disparity between the arthropod communities of the CRS and maize can also be attributed to the differences in vegetation densities between the two habitats and habitat preferences of different species because of their innate dispersal ability (Ebeling et al. 2018; Musters et al. 2022).

Furthermore, the differences in aerial arthropod patterns between the latter two habitats could be ascribed to the presence of flowering plants in the CRS that attracted different species of flying insects. Diverse field margins attract large numbers of pollinators, pollen feeders and non-pollinating species (Ouvrard et al. 2018). Interestingly, only species richness and Margalef's diversity differed between the CRS and the nearest (5 m) sampling stations to it, which could be ascribed to the high mobility of flying insects (Salces-Castellano et al. 2021; Baselga et al. 2012) and their dispersal into the maize field.

One of the dominant flying arthropod species recorded during this study, which also was responsible for a high percentage of dissimilarity between the communities was the spotted maize beetle (*A. atromaculatus*). The high abundance of this beetle can be ascribed to the abundance of maize pollen throughout the flowering period when this study was conducted (Van den Berg et al. 2008). Van den Berg et al. (2008) reported that the abundance of spotted maize beetles can rapidly increase during maize flowering.

A total of 967 individuals from 14 different morpho-species of Scarabaeidae were collected during this study. Of these, four morpho-species were responsible for the largest percentage of dissimilarity within the maize fields (different distances). This could be due to their aversion to disturbances (Gómez-Cifuentes et al. 2023) which is a common occurrence in the maize fields, and their preference for less disturbed habitats such as CRS. Similarly, Carabidae (3 morpho-species) and Tenebrionidae (3 morpho-species) both contributed to the dissimilarity between the different distance intervals within the maize fields, as well as the maize fields and CRS. Carabidae, as with Scarabaeidae, benefit from increased plant diversity which provide favourable habitats for these organisms. Rischen et al. (2021) reported that conservation strategies such as wildflower strips, grassland fallows and grassy wheat margins sustained a higher diversity of carabids, as well as carabids with larger body size, in comparison to cultivated wheat fields. Similarly, Lövei and Magura (2016) reported that some carabid species use field margins as overwintering habitats.

The CRS not only acts as a refuge or overwintering habitat but could also serve as a corridor between various agricultural fields. The abundance of floral components and the high diversity of Apidae and Muscidae in the CRS is therefore not surprising. The latter two arthropod families both contributed to the dissimilarity recorded for the aerial arthropod communities between and within the two habitats (Gámez-Virués et al. 2008; Doublet et al. 2022). Maize plants produce very high numbers of pollen grains and are wind pollinated. Although maize cultivation does not rely on the presence of these pollinating arthropod families, the crop contributes to the sustaining of pollinators and therefore indirectly supports healthy pollinator communities which benefit other plants within this ecosystem.

This study showed the presence of a large diversity of epigeal and aerial arthropods of various functional groups within this maize-based agroecosystem. The inclusion of refuges can benefit these arthropod populations, not only through facilitating their establishment, but also through serving as a habitat from where dispersal into the adjacent arable land can take place, and to improve movement between habitats as the biological requirements of

Table 4: Similarity percentage (SIMPER) analyses between pitfall- and pan trap samples at different distances into the maize field and between maize field and CRS. Arthropod families (with number of morphospecies in brackets) that cumulatively contributed to 50 % of the dissimilarity is listed. It should be noted that arthropods contributing to overall dissimilarity within maize field (across distances) were pooled to display families with the greatest contribution. *Contrib. = average contribution of each family to dissimilarity (%) and **Cumu. = Cumulative contribution (%).

Pitfall trap						Pan trap					
Overall Dissimilarity: 67.28%						**Overall Dissimilarity: 75.11%**					
Distances into Maize field			**Between Maize field and CRS**			**Distances into Maize field**			**Between Maize field and CRS**		
Families	**Contrib.**	**Cumu.**	**Families**	**Contrib.**	**Cumu.**	**Families**	**Contrib.**	**Cumu.**	**Families**	**Contrib.**	**Cumu.**
Scarabaeidae (4)	10.56	10.56	Carabidae (3)	7.22	7.22	Muscidae (1)	12.81	12.81	Muscidae (5)	12.52	12.52
Tenebrionidae (3)	9.17	19.73	Tenebrionidae (3)	5.49	12.72	Melyridae (1)	9.67	22.48	Melyridae (1)	6.88	19.4
Carabidae (2)	4.22	23.95	Staphylinidae (2)	4.68	17.34	Apidae (2)	9.35	31.83	Apidae (1)	4.74	24.14
Muscidae (2)	4.18	28.13	Muscidae (2)	3.53	20.93	Ceratopogonidae (1)	3.83	35.66	Aphididae (1)	3.99	28.13
Cicindelidae (1)	3.37	31.5	Nitidulidae (1)	3.49	24.42	Aphididae (1)	3.44	39.10	Formicidae(1)	2.94	31.07
Miridae (1)	3.19	34.69	Melyridae (1)	3.13	27.55	Sciaridae (1)	3.16	42.26	Braconidae(1)	2.69	33.76
Dermaptera (1)	3.125	37.82	Lygaeidae (1)	2.99	30.53	Melittidae (1)	3.13	45.39	Ceratopogonidae (1)	2.48	36.24
Chilopoda (1)	2.58	40.40	Aphididae (1)	2.76	33.29	Dolichopodidae (1)	2.95	48.34	Sciaridae(1)	2.44	38.68
Diplopoda (1)	2.48	42.88	Sciaridae (1)	2.14	35.43	Lygaeidae(1)	2.84	51.18	Lygaeidae(1)	2.27	40.95
Elateridae (1)	2.06	44.94	Braconidae (1)	2.06	37.49				Miridae(1)	2.19	43.14
Anthicidae (1)	2.00	46.94	Miridae (1)	1.78	39.27				Noctuidae(1)	1.79	44.93
Nitidulidae (1)	1.92	48.86	Formicidae (1)	1.76	41.02				Dolichopodidae(1)	1.71	46.64
Dolichopodidae (1)	1.78	50.64	Drosophilidae (1)	1.67	42.69				Melittidae(1)	1.70	48.34
			Curculionidae (1)	1.58	44.27				Calliphoridae(1)	1.69	50.03
			Scarabaeidae (1)	1.49	45.75				Phoridae(1)	1.62	51.65
			Diplopoda (1)	1.47	47.22						
			Dermaptera (1)	1.42	48.65						
			Cicindelidae (1)	1.36	50.01						

the arthropod changes. Similar suggestions regarding parasitoid communities in vineyards with adjacent non-crop habitats have been made by Segoli et al. (2020). However, other benefits could also arise from the establishment of CRS in agroecosystems. For example, Nitidulidae beetles, which generally feed on decaying fruits, organic matter and sap/nectar producing plants (Dagobert et al. 2008), are attracted to plant communities such as that within the CRS, because of the presence of abundant floral components.

Since Bt maize was planted in this study, no pesticides were applied on this farm during the current or the previous season. Bt maize does not have any direct effects on arthropod diversity in crop fields, except for certain lepidopteran target species (Truter et al. 2014). Furthermore, Carpenter (2011) reported that Bt crops have an indirect positive influence on biodiversity since it reduces the need for insecticide use on maize. An additional benefit of landscape enrichment such as the planting of CRS could be that it creates refuges to arthropods during agricultural disturbances such as fertilizer and herbicide applications and during the harvesting process.

This study highlights how the enrichment of field margins influences arthropod abundance and richness within a maize agroecosystem. This suggests that the presence of a CRS could not only be a refuge habitat for a variety of arthropod species, but aid in sustaining these arthropod communities. This study indicates that the presence of cultivated refuge strips could sustain increased arthropod diversity. Since not all beneficial arthropods are influenced by similar factors, more studies of this nature are required to investigate the underlying mechanisms that determine the movement and prevalence of beneficial arthropods in agroecosystems with landscape enhancements. This information will enable a better understanding of how community composition and spatio-temporal patterns of beneficial organisms change due to the presence of CRS. If beneficial arthropods respond positively to enhanced landscapes where they also suppress pest numbers, this can be recommended as part of conservation biocontrol strategies for maize pests.

CONCLUSION

This study showed that the presence of cultivated refuge strips in a monocrop maize field resulted in increased arthropod diversity during the flowering stages of maize. The CRS supported a higher diversity of arthropods and distinct arthropod communities were present within the CRS and maize field. This is ascribed to habitat preferences and more niche opportunities that were present within the CRS. Further studies should be conducted to compare the diversity of beneficial arthropods within refuges and maize fields throughout the cropping season, at further distances from refuges into maize fields.

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