Ecotone Effects on Arthropod Biodiversity in Texas Sorghum Field Edges and Within

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Abstract: High levels of arthropod biodiversity are indicative of a healthy environment and bring valuable benefits to agroecosystems, providing diverse functions like pollination, decomposition, and predation of crop pests by natural enemies. The intensification of agricultural practices often changes the neighboring habitats, creating new man-made environments that alter arthropod biodiversity within and around agroecosystems. These man-made ecotones, ecosystems made of two or more bordering habitats, are of great importance to integrated pest management systems and conservation efforts as spatial control of pests has been underutilized and understudied in the agricultural space for years. To assess these differences in biodiversity within and around Texas sorghum fields, an arthropod biodiversity survey over a 5-week period was conducted. Overall, this study covered a total of thirty-three collections, sampling arthropods across Texas sorghum fields that shared a border with sorghum, cotton, or semi-natural land ecotones, extending from the edge of the field's border to 150 meters within the field. Collected specimens were identified to the family-level taxon, and statistical analysis was conducted to measure biodiversity. Field surveys revealed that sorghum fields bordering semi-natural, cotton, or sorghum ecotones exhibited no significant differences in biodiversity near the borders as a result of ecotonal differences. Yet, distance from ecotone edges may play a significant factor. Increasing our understanding of impacts related to spatial or ecotonal changes on biodiversity in Texas field crops, like sorghum, and the surrounding ecosystems may provide valuable information regarding environmental performance and pest monitoring for integrated pest management.

Keywords: *Ecotone, biodiversity, sorghum, arthropods*

With the advent of agricultural intensification, ecotones have had an increasing rise in number. Monocultural crop fields are regularly maintained and developed as they replace the natural vegetation they displace. The displacement of the natural habitats that crop fields and these new ecotones have replaced could potentially have interactions with the environment that could be of great benefit or detriment to the environment. Specifically, the levels of biodiversity that are present within agricultural ecotones may provide enhanced biological control, directly affect pests negatively, or improve crop production (Gurr, et al. 2003, Scherr and McNeely 2007). Past studies have confirmed that agroecosystems comprised of field edges sharing borders with diverse habitats or ecotones, increase the biodiversity in that area (Nguyen and Nansen 2018, Knapp et al. 2022, Botha. M, et al. 2015, Macfadyen. S. 2015).

As such, it has become increasingly important for environmental, conservation, and agricultural studies to observe potential interactions of natural vegetation-crop ecotones with their surrounding environments. Increased use of pesticides has detrimental effects on the environment and the surrounding ecosystems when used for crop management (Sattler. C. et al. 2020). Reducing pesticide use in agricultural fields through refined methods used in integrated pest management (IPM) such as cultural or mechanical procedures is preferred in place of chemical controls. However, many underutilized methods of control, such as spatial practices are not well documented for IPM (Macfadyen. S. 2015). Specifically, the spatial interactions between agricultural ecotones and associated biodiversity are sparsely studied in the U.S., where sorghum is a major crop. Should more diverse ecotones provide a boost in biodiversity, then the benefits of spatial methods of integrated pest management or conservation efforts could be extremely beneficial. This paper analyzes the levels of biodiversity associated with arthropods within sorghum field edges and whether adjacent ecotones provide benefits to biodiversity in agroecosystems.

Materials and Methods

This study occurred in Corpus Christi, Texas, and Mathis, Texas during a five-week period in the year 2023 from late May to the end of June. Sampling was conducted twice a week along sorghum field edges at 0m, 50m, and 150m transects. Sorghum field edges that were sampled consisted of sorghum crops in the 7-9 growth stage in fields that bordered other fields of sorghum, cotton, or natural vegetation.

Sampling Design

Arthropod sampling utilized a sweep net (Bioquip, Compton, CA) and a beat bucket (Leaktite Corp., Leominster, MA). The sweep net offered arthropod capture within the crop rows along the sorghum leaves while the beat bucket would obtain arthropods on the sorghum heads. At each transect, 30 random sweeps of the net along crop rows and beating 20 sorghum heads into the beat bucket were determined to be enough to obtain a representative sample.

Preservation

At each transect, captured arthropods were transferred to a 1-gallon Ziploc bag (S.C. Johnson, Racine, WI) before being placed in a cooler (Igloo Products Corp. Katy, TX) with ice. The samples were then transferred to a freezer for preservation. The separation of samples from any plant debris within plastic bags consisted of using a testing sieve (W.S. Tyler, Mentor, Ohio) and forceps (Bioquip, Compton, CA) to manually separate individual samples before placing the arthropod samples back into the plastic bags to be frozen once again.

Identification

Adult arthropod samples were recorded and identified down to family or, if possible, to species using the identification keys of Borror and Delong (Johnson, N., and Triplehorn, C.A., 2004). Larval and nymphal specimens were identified whenever possible and recorded separately from adult specimens.

Statistical Analysis

Statistical analysis was conducted utilizing two different indices for the assessment of species richness and evenness. The Shannon-Weiner Biodiversity Index uses an in-depth analysis of species richness to provide a biodiversity value between zero and infinity. The Simpson Biodiversity Index uses an in-depth analysis of species evenness to provide a biodiversity value between zero and one. In both indices, a higher value is indicative of higher levels of biodiversity. Statistical analysis was conducted through an ANOVA two-way test and Tukey post-hoc test using a coding program known as R (v. 4.2.3).

Results

An analysis of biodiversity levels in agroecosystems comprised of sorghum fields bordering different ecotones yielded insignificant results based on distance from ecotone edge and ecotone type. Over 33 collections, 4,951 insects were identified to belong to ten different taxonomic orders and 50 different families. Based on the Shannon-Weiner Biodiversity Index (S-W), all ecotones tested displayed slightly higher levels of biodiversity based on ecotone type. The S-W produced biodiversity values of 2.062778309 for semi-natural ecotones, 1.900222775 for cotton ecotones, and 1.812542233 for sorghum ecotones on average. Biodiversity values using the Simpson Index (SI) showed less variation in biodiversity values across ecotones. The SI produced biodiversity values of 0.778098 for semi-natural ecotones, 0.773807 for cotton ecotones, and 0.810894 for sorghum ecotones (Fig 1). A general downward trend in biodiversity was indicated farther away from the ecotone's edge in all ecotones except for sorghum-edge ecotones which showed the opposite (Fig 2).

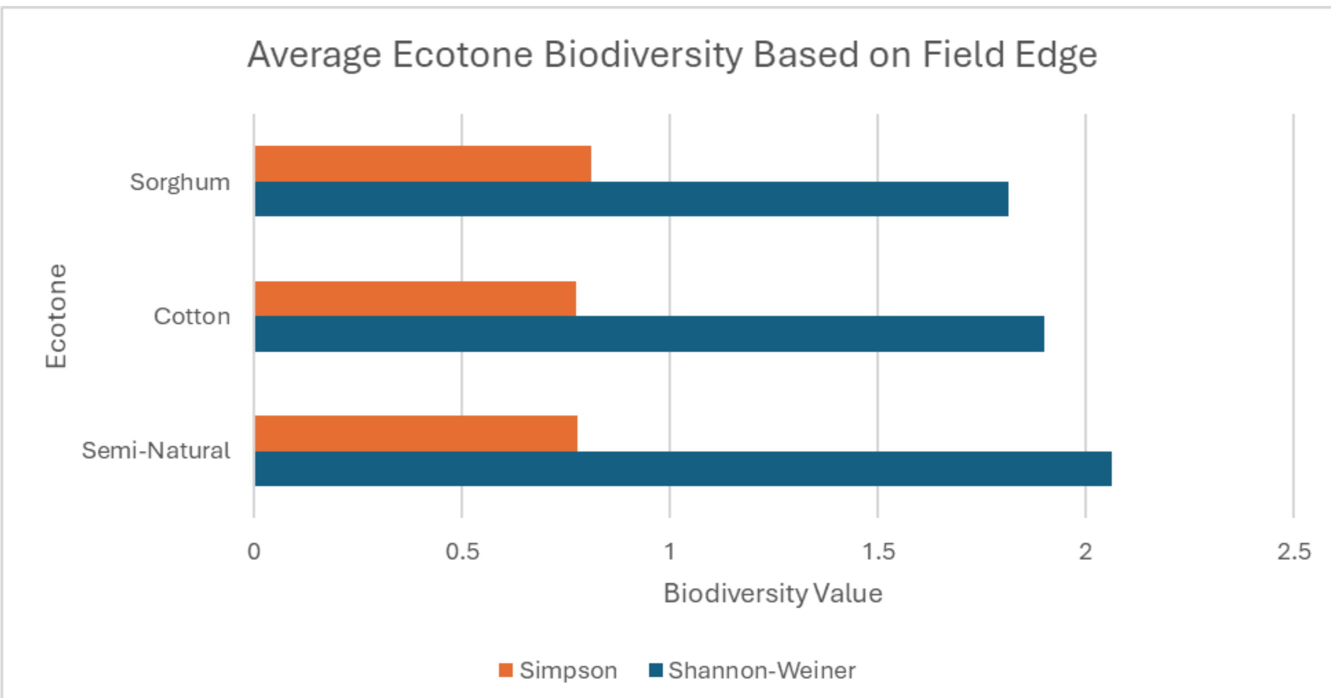

Fig 1: Average biodiversity values for each ecotone. Biodiversity values generated from the Shannon-Weiner Index (Solid) indicate higher levels of biodiversity the larger the value is. Biodiversity values generated from the Simpson Index (Striped) indicate higher levels as the value approaches 1 (0 < 1).

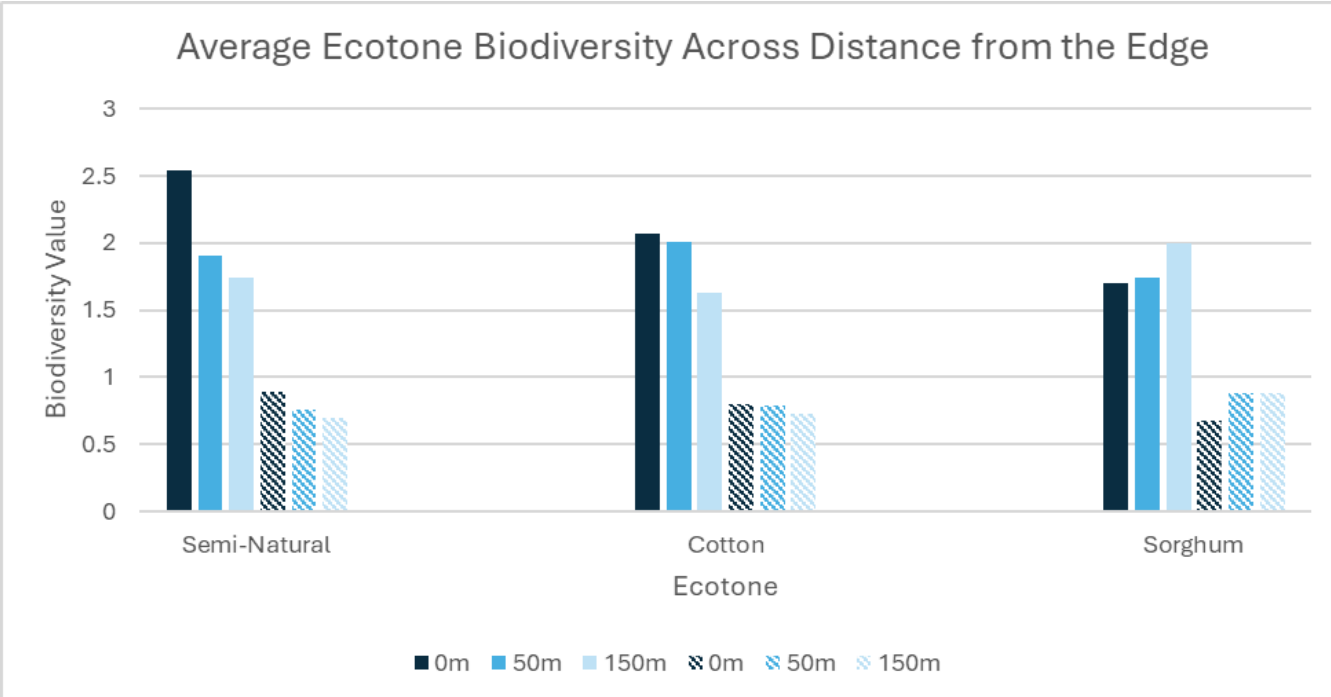

Fig 2: Average biodiversity values for each ecotone at every transect. Biodiversity values generated from the Shannon-Weiner Index (Solid) indicate higher levels of biodiversity the larger the value is. Biodiversity values generated from the Simpson Index (Striped) indicate higher levels as the value approaches 1 (0 < 1).

A two-way ANOVA of the Shannon-Weiner Biodiversity Index data showed no significance in biodiversity values based on ecotone type (P = 0.29854) or distance away from the ecotone edge combined with type (P = 0.10057). Distance from ecotone edges alone showed significance to biodiversity values (P = 0.02309). A Tukey post-hoc test of the data shows that the only significant difference between tested transects away from ecotone edges (0m, 50, and 150m) was between the edge of the ecotone and the 150m transect (P = 0.0178728). A two-way ANOVA of the Simpson Biodiversity Index data displayed no significance in biodiversity levels between ecotone, distance, or both (P = 0.77154, P = 0.37186, P = 0.06157) respectively.

Discussion

In the wild, naturally occurring ecotones generally present increased areas of biodiversity as the combination of different habitats provides each of their elements to support more diverse life for various species. Empirically, most studies confirm that the levels of arthropod biodiversity in agricultural ecotones are higher on average at diverse field edges than anywhere else (Nguyen and Nansen 2018, Knapp et al. 2022, Botha. M, et al. 2015, Macfadyen. S. 2015). However, this is not a consistent result as many examples note that biodiversity is consistent regardless of distance from the field edge or ecotone (Dangerfield, et al. 2003, Wimp and Murphy 2021,). Generally, the consensus of higher biodiversity at field edges along diverse habitats comes from different “edge effects” that have been documented in agroecosystems. Besides allowing for a greater host range that attracts a wider variety of insects, in crops such as sorghum, trapping effects along field edges initiate higher levels of biodiversity in crop fields (Olson and Andow 2008, Nguyen and Nansen 2018, Holland and Fahrig 2000). Multiple edge effects are present in the trapping of insects within field edges or in suppressing their dispersal from variables such as wind and vegetation. In particular, sorghum height allows for enhanced trapping effects when planted next to shorter or taller vegetation due to wind trapping (Corbett and Rosenheim 1996, Cleugh and Hughes 2002). The means of sorghum fields to contain enhanced biodiversity are all present in a variety of field effects. Yet, the lack of consistency across these factors may hinder biodiversity (Dangerfield, et al. 2003).

Results from this study display that there is a lack of significant differences among biodiversity levels across field ecotones and in some cases across distances. The only significant differences in biodiversity were found utilizing the Shannon-Weiner Biodiversity Index across the field edge and 150m transects. This pattern was consistent with all data calculated with the Shannon-Weiner Biodiversity Index data. Using the Simpson Biodiversity Index data indicated that there was no significance for either distance or field ecotone. While both indices are popularly used in calculations for biodiversity levels, the main difference between the two indices is that the Simpson Biodiversity Index accounts for species dominance, or the proportion of that species population in comparison to others. The Shannon-Weiner index focuses primarily on species richness, the number of different species. This implies that while there are differences in biodiversity across different distances, the composition of fields is extremely uneven. Past studies support that herbivore insect behaviors and field effects may be responsible as ecological interactions can alter population dynamics and community structures regardless of biodiversity levels (Bach, Catherine E. 1988). It is also likely that the inconsistencies present in habitats and sampling may have skewed results. Initially, habitat sampling across ecotones like that of the natural vegetation was sampled across varied bordering habitats (forest, grassland, etc.) to obtain a larger and more representative sample. However, further research may explain why there is a lack of significance in the data when most empirical studies display an increase in biodiversity as the ecotone becomes more varied at the field's edge (Dangerfield, et al. 2003). Sampling efforts could also have been increased as most previously conducted studies captured a minimum of 10,000 individual specimens or conducted their experiments across larger periods for increased numbers of samples (Macfayden, S. et al. 2015, Holland and Fahrig 2000). Sampling efforts for this study concluded with 4,951 collected specimens across a five-week period that likely may not present a true representation of similar data. Additionally, sampling across habitats was conducted unevenly as events such as weather, pesticide spray schedules, etc. interfered with sampling.

The implications of this study still show significance to changes in community composition among different field ecotones in sorghum across distances. Understanding population dynamics and community structure along field edges can provide valuable information in the field of pest management assuming more specific data on the compositions of the species inhabiting the field edges per ecotone are recorded. Managing these sorts of field effects can also play a large role in ecosystem management, function or conservation.

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