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Original Research

Adaptive Multipaddock (AMP) Pasture Management Increases Arthropod Community Guild Diversity Without Increasing Pests

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ABSTRACT

Adaptive multipaddock (AMP) grazing is a form livestock management that uses high stock density, frequent herd rotation, and long adaptive plant recovery periods to produce punctuated disturbances within pastures. This form of livestock management may benefit pasture biodiversity and ecosystem function. Arthropods are key to ecosystem functionality through the fulfillment of many ecological niches in pasture ecosystems like dung burial, pest control, and pollination. However, the effect of AMP grazing on arthropod communities has not been well studied. We assessed the effect of AMP grazing on arthropod community composition. Foliar, soil, and dung arthropod communities were collected from AMP and conventionally grazed (CG) pastures located in the southeastern US. Arthropod abundance, species richness, diversity, and guild composition were compared between grazing treatments. The herbaceous standing plant diversity was recorded in the immediate vicinity of arthropod sampling. AMP grazed pastures exhibited higher foliar arthropod species richness, along with higher foliar and dung guild diversity. The effects of AMP grazing on the arthropod community were likely correlated to changes to the vegetative community resulting from AMP grazing. No differences in pest abundance or species diversity were found between the AMP and CG pastures. This study shows AMP pasture management has a positive effect of arthropod community composition, which is likely to be an important mechanism to facilitating ecosystem services in AMP pastures.

Introduction

Arthropods are an important component of rangeland ecosystems, performing numerous ecosystem services and linking resources to higher and lower trophic levels within the system (Belovsky and Slade, 2000; Andersen et al. 2004; Whiles and Charlton 2006; Prather et al. 2013; Pecenka and Lundgren 2018; Goosey et al. 2019). For example, dung beetles efficiently decompose livestock dung, effectively cycling nutrients and reducing pest habitat simultaneously (Losey and Vaughan 2006). Modifications to arthropod communities in rangeland systems can have extensive effects on ecosystem function. These effects are multifaceted and difficult to predict across the entire arthropod community. Like when increased grazing intensity led to significantly more terrestrial invertebrates in adjacent riparian areas to supply more food for fish, or grassland use intensity reduced invertebrate herbivory, implying a reduction in nutrient and energy cycling (Saunders and Fausch 2007; Neff 2021). Consequently, management decisions that alter arthropod communities need to be assessed carefully as those decisions can either benefit or hinder rancher goals.

Grazing affects plant community composition, productivity, and physical structure (Olff and Ritchie 1998; Joern and Laws 2013), and arthropods are sensitive to these changes to rangeland vegetation (Koricheva et al. 2000; O'Neill et al. 2010; Zhu et al. 2012). For example, rotational or intermittent grazing events produce punctuated disturbances that induce spatial heterogeneity (Adler et al. 2001), which can produce high levels of arthropod diversity (van Klink et al. 2015). Thus, the method of grazing management implemented on one of the largest ecosystems on earth could have a significant effect on arthropod diversity and community structure within the rangeland biome.

Adaptive multipaddock (AMP) grazing is a pasture management system that uses herd management techniques like multiple paddocks per herd, high animal densities, short periods of grazing, and adequate recovery periods for vegetation (Teague and Kreuter 2020). Adequate recovery period is dependent on management goals, but generally requires plants to undergo the rapid growth

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phase and elongation of the apical meristem, or under some circumstances set seed, establish a desired structure, germinate, and establish seedlings or some other measure of growth/regrowth (Savory and Parsons 1980; Savory and Butterfield 1999; Steffens et al. 2013). Animal numbers are adaptively adjusted to match variations of available forage within and between grazing seasons to ensure adequate forage amounts for animal needs and soil cover for ecological functioning (Teague and Kreuter 2020). This form of livestock management produces short, punctuated disturbances within rangelands (i.e., paddocks) to improve the ecological function of the land (Teague et al. 2013). AMP grazing improves soil health and plant communities by enhancing soil organic matter, soil aggregation, water holding capacity, and nutrient availability (Teague et al. 2011). While the effects of AMP grazing on plant communities are, in general, described as positive (Hillenbrand et al. 2019; Wang et al. 2021), the specific effects of AMP grazing on plant community attributes, e.g., diversity, structure, bare ground, etc. do not always uniformly improve with AMP grazing. For example, Apfelbaum et al. (2022) found that AMP grazing both increased and decreased percent bare ground, and invasive perennial plant species richness and abundance relative to conventional continuous grazing. These discrepancies likely extend from the plant community to the arthropod community, as plant diversity is typically positively correlated with arthropod diversity and affects arthropod community composition (Crutsinger et al. 2006; Johnson et al. 2006; Haddad et al. 2009; Joern and Laws 2013). Because arthropod community structure is often tied to plant communities, and AMP grazing effects plant community attributes differently relative to conventional continuous grazing, it is difficult to predict how AMP grazing will affect arthropod community structure. Consequently, understanding the impacts of AMP grazing on the arthropod community is critical to comprehending how this pasture management method generates arthropod derived ecosystem services for ranchers. Therefore, we compared arthropod community diversity and functional guild composition of AMP grazed pastures to conventionally grazed (CG) pastures. We hypothesized AMP pastures are high-quality habitats for arthropods, and we expected higher arthropod abundance and diversity in AMP than CG pastures.

Methods

Study sites

The southeastern US was the focal region of the study. Potential participating ranchers were recruited using a combination of online surveys and grazing organization/agency referral, e.g., USDA-NRCS, Grassfed exchange, etc. Responses to these inquiries were reviewed by grazing scientists Drs. Richard Teague and Allen Williams, and followed by field validation visits by Drs. Teague and Tom Hunt, a professional soil scientist, to confirm grazing and land-use history during the previous 10 y. Specific management criteria considered for selection of sample sites included land use history, soil types, cattle stocking rates, pesticide usage, fertilizer usage, historic weather patterns, size and number of paddocks per herd, mowing, history of planting, and length of current management history. This information is described in detail in Supplementary Table 1, Johnson et al. (2022), and Mosier et al. (2021) for reference, and was used to select pairs from each region with similar criteria from each category. Within the context of site history, ranch managers implemented various livestock management practices to fulfill their ranching goals, including the ability to adjust stocking rates during the grazing season as deemed necessary to accommodate for adverse weather conditions. Stocking rates for each treatment pair are recorded in Table S1, and it should be noted that stocking rates were not always the same between treatment pairs. Specific livestock management practices used to categorize sites into AMP or CG treatment groups based on meeting the majority (≥4) of the criteria are described in Table 1. Practices used to categorize pastures as AMP or CG included stocking density, rotation frequency, and insecticide usage. This method of categorization was formulated in accordance with AMP practices at each location in response to changing conditions as defined by Teague et al. (2013) and has been utilized to distinguish AMP from CG pastures in previous studies (Pecenka and Lundgren 2019; Fenster et al. 2021; Mosier et al. 2021; Schmid and Lundgren 2022). Grazing treatments were paired (<8 km apart) across study locations. Sampled pastures were located in Kentucky ($n = 2$), Tennessee ($n = 2$), Alabama ($n = 4$), and Mississippi ($n = 2$) (Fig. 1).

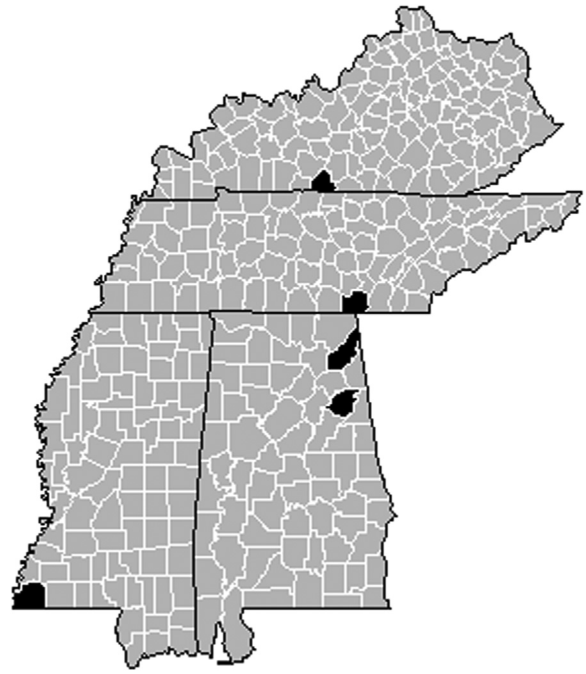

Figure 1. Pastures ($n = 10$) sampled for this study, highlighted in black, were located in Allen County, KY; Marion County, TN; DeKalb County, AL; Calhoun County, AL; and Wilkinson County, MS. All sites were located within the Eastern Temperate Forest ecoregion of the United States. Specifically, Allen County, KY sites were in the Interior Plateau of the Southeastern USA Plains, Marion County, TN and DeKalb County, AL sites were in the Southwestern Appalachians of the Ozark Ouachita-Appalachian Forests, Calhoun County, AL sites were in the Ridge and Valley of the Ozark Ouachita-Appalachian Forests, and Wilkinson County, MS sites were in the Mississippi Valley Loess Plains of the Southeastern USA Plains.

Sampling procedure

The arthropod community was sampled three times during the 2018 grazing season (May 1–4, July 23–28, and September 29–October 3), with the foliar and soil communities sampled on all three dates and the dung community only sampled during the July and September sampling dates. Two sampling areas were established 100 m apart, on average, in each pasture. Each sampling area contained three transect lines (45.7 m) run in parallel spaced 15.2 m apart, for a total of six transects per pasture. The foliar and soil arthropod communities were sampled along these transect lines, while the dung community was sampled from fresh (2–5 d old) dung pats from the cattle herd grazing each pasture, as this age of pat has been shown to contain peak arthropod abundance and diversity (Pecenka and Lundgren 2018).

The foliar arthropod community was sampled with a sweep net (38 cm diameter) from pasture foliage at the midpoint of each of the three transect lines from the first sampling area in each pas-

Table 1
Composite rank score and associated ranching system designation of individual ranches sampled for this study ($n = 10$).

Location (county and state)	Stocking density	Rotation frequency	Insecticide/wormer	Composite rank score	System designation
Allen, KY	2	2	1	5	AMP
Allen, KY	0	0	0	0	Conventional
Marion, TN	2	2	2	6	AMP
Marion, TN	0	0	0	0	Conventional
Dekalb, AL	2	2	1	5	AMP
Dekalb, AL	0	1	1	2	Conventional
Calhoun, AL	2	2	2	6	AMP
Calhoun, AL	0	0	1	1	Conventional
Wilkinson, MS	2	2	1	5	AMP
Wilkinson, MS	1	0	0	1	Conventional

Ranch systems were categorized based on cattle stocking density, herd rotation frequency, and insecticide/anthelmintic (wormer) use. These three ranch management practices were scored 0 to 2, with higher numbers reflecting adaptive multipaddock (AMP) practices. Stocking density was divided into <5 animal units (AU)/ha (0), 5 to 10 AU/ha (1), and > 10 AU/ha (2). Rotation frequency was divided into >30 d rotation (0), 10 to 30 d rotation (1), and <10 d rotation (2). Insecticide/wormer application was divided into multiple applications (0), application once per year to individuals in herd that required treatment (1), and no insecticide or wormers (2). Ranches whose composite rank score are ≥4 were considered AMP grazing, and ranches with rank scores ≤3 were considered conventionally grazed (CG).

ture ($n = 3$ sweep samples/pasture; 50 sweeps/sample). Collected arthropods were stored in plastic bags containing 3 mL of 70% isopropyl alcohol to preserve specimens, and kept on ice in the field. Upon returning to the laboratory, samples were stored at −18 °C until specimens could be separated from loose vegetation, and preserved in 70% isopropyl alcohol for curation.

The soil and dung arthropod communities were collected using core sampling (10 cm diameter, 10 cm deep). Soil cores were extracted twice (at the first and third quarter marks) along two of the transect lines at both sampling areas ($n = 8$ soil cores/pasture). Dung cores were taken from randomly selected dung pats within the pasture ($n = 5$ dung cores/ranch). All soil and dung cores were kept on ice upon collection from the field until they could be returned to the laboratory (60 h). Upon return to the laboratory, cores were placed in a Berlese funnel extraction system for 7 d, which permitted each soil/dung core to completely dry and all arthropods to evacuate from the core (Pecenka and Lundgren 2018). Upon completion of the Berlese system arthropods were stored in 70% isopropyl alcohol, until they could be identified and cataloged.

Vegetation biomass samples were collected from both arthropod sampling areas within pastures ($n = 30$ quadrats/sampling area) at similar times arthropods were collected in spring, summer, and fall. Biomass was clipped at ground level in 0.10 m^2 quadrats and plant species composition was estimated using the dry-weight-rank method as outlined by Dowhower et al. (2001). Harvested biomass dry weight was recorded for each species and used to generate a Shannon H' diversity index.

Arthropod community composition

Each collected arthropod specimen was identified to the lowest taxonomic level possible. Due to a lack of taxonomic references and time constraints, no effort was made to identify mites (Arachnida: Acari) beyond the class level, Protura beyond the class level, thrips (Insecta: Thysanoptera) beyond the ordinal level, Symphyla beyond the class level, millipedes (Diplopoda: Julida) beyond the ordinal level, Diplura beyond the family level, and springtails (Hexapoda: Collembola) beyond the family level. All other specimens were identified to genus or species level and assigned a morphospecies identification number. Larvae of holometabolous insects were considered as morphospecies independent from adult specimens owing to their differences in ecological function. Morphospecies were assigned to one of nine functional guilds based on knowledge and current hypotheses regarding the ecology of these organisms, a sampling of the texts that were most utilized texts are cited (Borror et al. 1989; Harpootlian, 2001; Larochelle and Lariviere 2003; Powell and Opler 2009; Whitfield and Purcell III 2013). The nine guilds assigned were: predator, parasitoid, pollinator, herbivore, granivore, coprophage, carrion, livestock pest, and other/unknown. Voucher specimens are deposited in the Mark F. Longfellow Collection, housed at Blue Dasher Farm (Estelline, South Dakota, USA).

Data analysis

Nonmetric dimensional scaling (NDS) ordination was used to assess differences in vegetation and arthropod community variance and composition between the two grazing treatments (AMP and CG) using the *betadisper* and *anodis* functions in the vegan package of R. Month of sampling and vegetation diversity were included in the model when assessing composition of the different arthropod communities. Upon finding no significant differences in heterogeneity of arthropod communities sampled from the two grazing treatments, the means of community metrics (abundance, species richness, species diversity and guild diversity) were analyzed for differences between grazing treatments.

The following metrics of the foliar, soil, and dung arthropod communities were compared between grazing treatments using two-way ANCOVA: total arthropod abundance, species richness, species diversity (Shannon H'), and guild diversity (Shannon H'). Vegetation diversity was the covariate in the ANCOVA model owing to the need to control for effects of vegetation diversity on arthropod communities. Grazing treatments and month served as the independent variables. All data conformed to the assumptions of ANCOVA. Owing to the small replication size and the inherent variability of arthropod community data collected across a large geographic area, statistical significance was set at $\alpha = 0.10$.

Results

Pasture vegetation and arthropod communities

A total of 126 251 arthropods were collected from the foliage, soil, and dung of the ten pastures. A complete inventory of arthropod specimens collected from this study can be found in Schmid et al. (2021). In brief, 52 128 arthropod individuals were collected from the foliar community, representing 759 morphospecies from four classes and 13 orders. The soil arthropod community was represented by 53 292 collected specimens, constituting 436 morphospecies from eight classes and 18 orders. Lastly, the 20 831 arthropod specimens were collected from dung pats, representing 234 morphospecies from six classes and 12 orders. The vegetation community contained 103 species. The biomass of the plant community was 40.9% warm season perennial grasses, 39.3% cool season perennial grasses, 6.2% legumes, 5.8% annual grasses, 4.1% perennial forbs, 3.0% annual forbs, and 0.7% sedges.

Table 2
Permutational multivariate analysis of variance (ADONIS) and homogeneity of dispersion results comparing vegetation and arthropod communities (foliar, soil, and dung communities) between grazing treatments of adaptive multipaddock (AMP) grazed and conventionally grazed (CG).

	ADONIS		Homogeneity of dispersion	
	F-ratio	*P*-value	F-ratio	*P*-value
Vegetation community				
Grazing treatment	1.95	0.01[1]	0.91	0.35
Month	2.38	0.01[1]		
Grazing treatment × month	0.83	0.15		
Foliar arthropod community				
Grazing treatment	1.55	0.05[1]	2.84	0.11
Month	3.43	0.01[1]		
Vegetation diversity	1.24	0.16		
Grazing treatment × month	0.75	0.92		
Grazing treatment × vegetation diversity	0.96	0.51		
Month × vegetation diversity	1.32	0.06[1]		
Grazing treatment × month × vegetation diversity	0.87	0.73		
Soil arthropod community				
Grazing treatment	1.56	0.10[1]	0.26	0.62
Month	1.89	0.01[1]		
Vegetation diversity	2.36	0.01[1]		
Grazing treatment × month	0.57	0.98		
Grazing treatment × vegetation diversity	0.96	0.50		
Month × vegetation diversity	0.79	0.78		
Grazing treatment × month × vegetation diversity	0.47	0.99		
Dung arthropod community				
Grazing treatment	0.88	0.63	1.08	0.31
Month	2.69	0.01[1]		
Vegetation diversity	1.37	0.07[1]		
Grazing treatment × month	0.71	0.89		
Grazing treatment × vegetation diversity	0.95	0.56		
Month × vegetation diversity	1.02	0.44		
Grazing treatment × month × vegetation diversity	0.76	0.80		

[1] Denotes statistically significant differences at $\alpha = 0.10$.

Vegetation and arthropod community compositions

Vegetation and arthropod community NDS analysis converged on solutions with stresses of 0.22, 0.19, 0.20, and 0.20 for the vegetation, foliar arthropod, soil arthropod, and dung arthropod communities, respectively. Month of sampling was consistently associated with the composition of all four measured communities (Table 2). Grazing treatment also had a significant effect on all community compositions, except for the dung arthropod community. Lastly, vegetation diversity was significantly associated with both soil and dung arthropod community composition. While NDS analysis showed grazing treatment was associated with vegetation, foliar, and soil arthropod community composition, variance between grazing treatments for each of the communities, including the dung arthropod community, showed homogeneity of dispersion (Table 2). This indicated that beta diversity of community compositions were not significantly different between grazing treatments.

Vegetation diversity

Mean vegetation diversity was significantly higher in the AMP pastures ($F_{1, 26} = 3.90$, $P = 0.05$) (Fig. 2), with the AMP grazed pastures having 22% higher diversity than the CG pastures.

Foliar arthropod community

Mean species richness and guild diversity were significantly higher, 33% and 25% higher, respectively, in the AMP grazed pastures (Table 3, Fig. 3B and D). Vegetation community diversity did not have a significant effect on any of the measured arthropod foliar community metrics (Table 3).

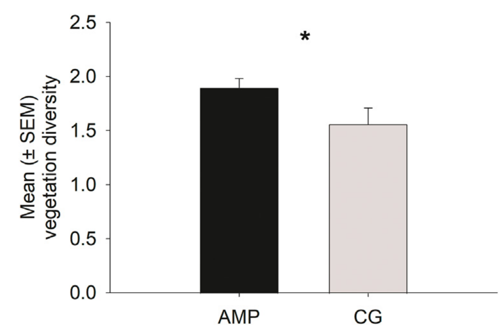

Figure 2. Mean ± SEM pasture vegetation diversity in adaptive multipaddock (AMP) and conventionally grazed (CG) pastures ($n = 10$). Statistical analysis was performed using one-way analysis of variance (ANOVA), (*) denotes statistical significance at $\alpha = 0.10$.

Soil arthropod community

Grazing treatment did not have a significant effect on soil arthropod community metrics (Table 3, Fig. 3). Rather, vegetation diversity was the significant driver of the soil arthropod community, affecting arthropod abundance, diversity, and guild diversity (Table 3), with plant diversity having a significant positive correlation with soil-dwelling arthropod abundance ($F_{1, 26} = 10.56$, $P < 0.01$) but a negative correlation with guild diversity ($F_{1, 26} = 5.75$, $P = 0.02$).

Dung arthropod community

Dung arthropod guild diversity differed significantly between grazing treatments (Table 3), with mean arthropod guild diversity being 23% higher in AMP grazed pastures (Fig. 3D). Vegetation diversity did not have a significant effect on any of the measured dung arthropod community metrics.

Table 3
Analysis of covariance results comparing arthropod community (foliar, soil, and dung communities) abundance, species richness, diversity (Shannon H'), evenness (Shannon equitability), guild diversity (Shannon H'), and guild evenness (Shannon equitability) in adaptive multipaddock (AMP) grazed and conventional grazed (CG) pastures.

	Foliar arthropods		Soil arthropods		Dung arthropods	
	F-ratio	*P*-value	F-ratio	*P*-value	F-ratio	*P*-value
Abundance						
Grazing treatment	0.14	0.71	2.67	0.12	1.60	0.22
Month	3.22	0.06[1]	1.35	0.28	1.62	0.22
Vegetation diversity	0.25	0.62	7.46	0.01[1]	1.22	0.29
Species richness						
Grazing treatment	5.13	0.03[1]	0.00	0.97	0.26	0.61
Month	5.57	0.01[1]	8.76	0.00[1]	4.00	0.06[1]
Vegetation diversity	0.90	0.35	0.92	0.35	0.61	0.44
Diversity						
Grazing treatment	2.28	0.15	1.44	0.24	0.97	0.34
Month	0.06	0.94	1.42	0.26	2.87	0.11
Vegetation diversity	0.30	0.59	3.25	0.08[1]	0.20	0.70
Guild diversity						
Grazing treatment	4.85	0.04[1]	2.76	0.11	3.26	0.09[1]
Month	1.11	0.35	0.28	0.76	0.76	0.40
Vegetation diversity	0.62	0.44	7.62	0.01[1]	0.31	0.58

[1] Denotes statistically significant differences at $\alpha = 0.10$.

Table 4
Percent (±SEM) pest abundance and species richness of arthropod community pests (foliar, soil, and dung communities) in adaptive multipaddock (AMP) grazed and conventional grazed (CG) pastures. Statistical analysis was performed using two-way analysis of variance (ANOVA).

	Foliar arthropods			Soil arthropods			Dung arthropods		
	AMP	CG	*P*-value	AMP	CG	*P*-value	AMP	CG	*P*-value
Percent arthropod pest abundance	1.08 ± 0.2%	2.14 ± 0.9%	0.35	3.09 ± 1.0%	2.96 ± 1.0%	0.96	1.97 ± 0.8%	1.63 ± 1.1%	0.80
Percent arthropod pest species richness	1.87 ± 0.3%	1.95 ± 0.3%	0.83	2.90 ± 0.6%	3.51 ± 0.5%	0.42	3.31 ± 0.9%	2.45 ± 0.6%	0.42

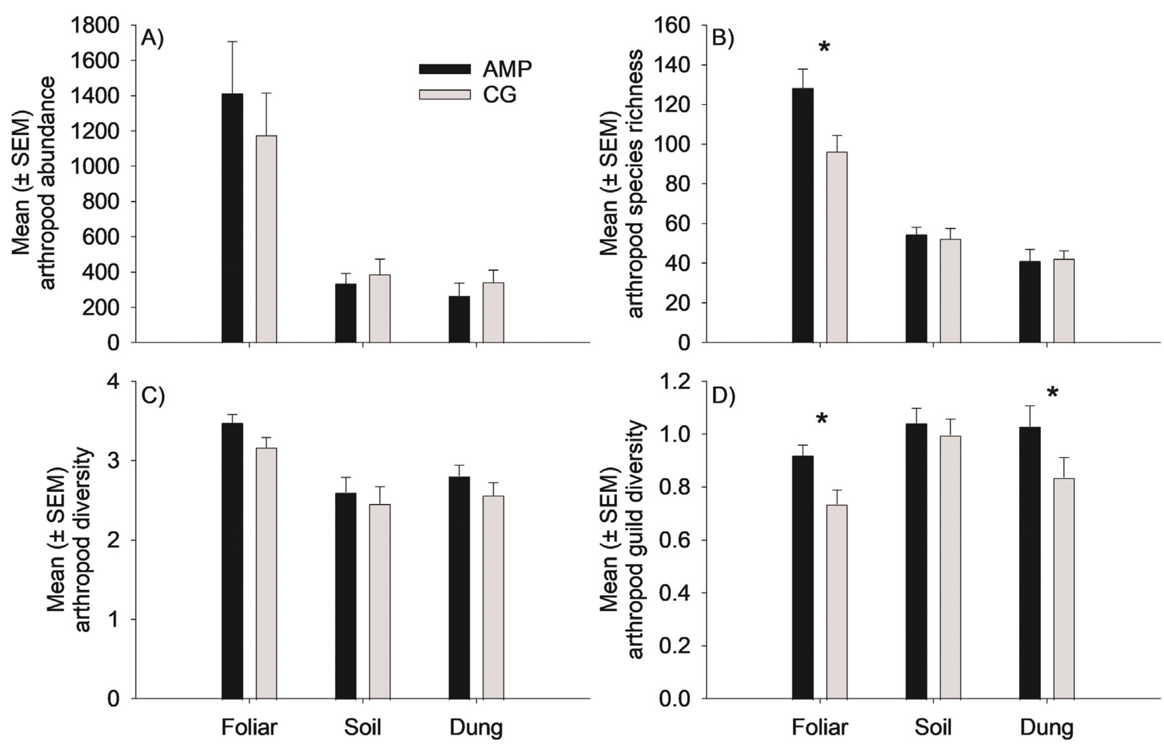

Figure 3. Mean ± SEM foliar-, soil-, and dung-dwelling arthropod community abundance **A,** species richness **B,** diversity **C,** and guild diversity **D,** in adaptive multipaddock (AMP) and conventionally grazed (CG) pastures ($n = 10$). Statistical analysis was performed using two-way analysis of covariance (ANCOVA), (*) denotes statistical significance at $\alpha = 0.10$.

Pest arthropod community

Overall, pest arthropods were infrequently collected from the pastures, and there were no significant differences in pest abundance or species richness between AMP and CG pastures (Table 4). Pest abundance was low in all three arthropod communities, with the highest percentage only constituting 3.09% of the community (Table 4). Species richness of arthropod pests showed a similar occurrence of pests, with the highest percentage of pest species in one of the arthropod communities only being 3.51% (Table 4).

Discussion

Our research on the effects of AMP grazing on arthropod communities contributes to the growing body of evidence that AMP grazing enhances biodiversity and ecosystem functionality (Hillenbrand et al. 2019; Mosier et al. 2021; Apfelbaum et al. 2022; Johnson et al. 2022). Our results show that AMP grazed pastures had higher foliar arthropod species richness, along with higher guild diversity in both the foliar and dung arthropod communities (Fig. 3). It should be noted, however, that this data was collected over the course of only one grazing season. As such, it cannot be determined if the differences in arthropod communities between the two grazing treatments were an anomaly that occurred during that particular year, or if it is a general trend sustained through time. This needs to be kept in mind when interpreting these results. While this research shows that AMP grazing fosters certain aspects of arthropod community diversity, the effects of AMP grazing on arthropod communities are likely tied to changes to the vegetative community resulting from AMP grazing, e.g., structure, diversity, ground cover. Understanding how the AMP grazing and vegetation community composition interplay to effect arthropod community composition will help to direct the utilization of AMP grazing as an arthropod conservation tool.

The manner in which arthropod community compositions varied between AMP and CG pastures was unexpected. Instead of the typical changes to arthropod communities linked to increased vegetation diversity, i.e., increased arthropod abundance, species richness, and diversity, the most substantial change to the arthropod community was to guild diversity. Both the foliar and dung arthropod communities had higher guild diversity in the AMP pastures (Table 3, Fig. 3D). The cause of the changes to guild diversity are likely, at least in part, due to alterations to the vegetative community from AMP grazing.

By design, AMP grazing is intended to improve the ecological function of pastures via adaptive management tailored to increase vegetative biomass, diversity, and structural heterogeneity (Teague et al. 2011; Wang et al. 2021; Apfelbaum et al. 2022). This appears to have happened in the AMP pastures of this study, as not only did we find increased vegetative diversity in the AMP pastures (Fig. 2), but when Wang et al. (2021) examined the plant community of the two Mississippi sites there was also higher vegetative landscape heterogeneity in the AMP pasture. As plant community structure diversifies and species richness increases, it typically results in increased availability of limiting resources, microhabitats, and suitability of abiotic conditions necessary for arthropod communities to diversify too (Joern and Laws 2013). While overall arthropod community abundance and diversity typically scales with increased plant community diversity and heterogeneity, arthropod community response can be idiosyncratic, showing both positive and negative associations depending on the species or functional guild (Knops et al. 1999; Joern 2005; Wardle et al. 2005; Sabais et al. 2011). This seems to be the case with our results, with community level arthropod abundance and diversity remaining similar between the two grazing treatments (Fig. 3), while the abundance of predator and parasitoid increased and the herbivorous guilds (herbivores and granivores) decreased (Fig. 4). It would be valuable to follow-up these results examining what specific alterations to plant community composition resulting from AMP grazing affect the arthropod guild community structure, and does it contribute to ecosystem services for ranchers.

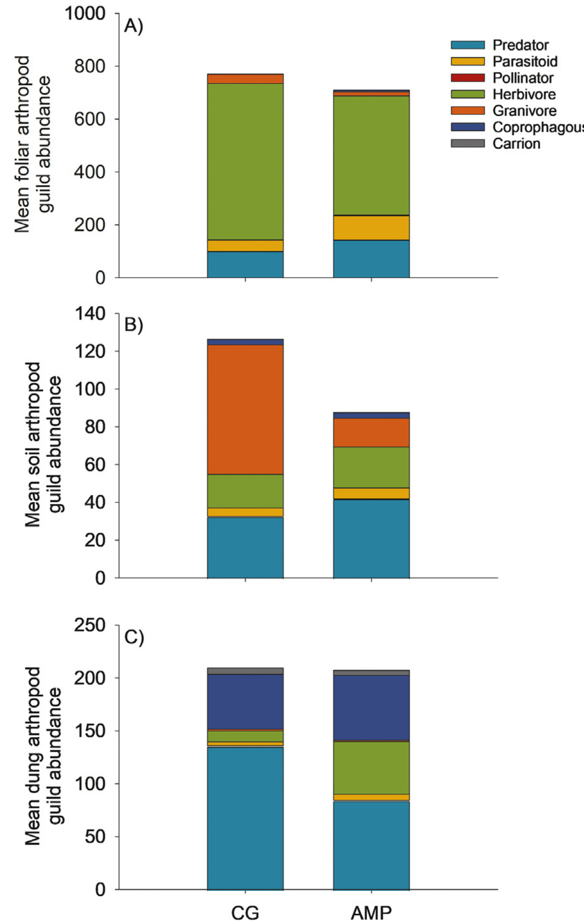

Figure 4. Mean arthropod guild abundance of the **A,** foliar, **B,** soil, and **C,** dung arthropod communities from adaptive multipaddock (AMP) and conventionally grazed (CG) pastures ($n = 10$).

An increased concentration of dung pats associated with high stock density, rotationally grazed pastures (like AMP grazed pastures) can affect dung arthropod community composition by increasing dung beetle abundance and species richness (Perrin et al. 2020; Wagner et al. 2020), which is similar to our results that show the AMP pastures had 18% and 384% higher abundance of coprophagous and herbivorous arthropods, respectively. Additionally, plant heterogeneity may also directly affect dung arthropod communities, like it does the foliar and soil arthropod communities. Vegetation type, for example, can influence two microhabitat conditions pertinent to coprophagous arthropod colonization of dung pats, temperature and humidity (Neita and Escobar, 2012; Jose and Dollinger 2019). Temperature and humidity regulate the dehydration rate of dung, which dictates the moisture content remaining in dung over time. Moisture content of dung is an important attribute for coprophagous insect colonization (Edwards 1991), since adult dung beetles feed on the fluid component of dung and telecoprid dung beetles need sufficient dung moisture to form and roll dung balls (Halffter and Matthews 1966; Al-Houty and Al-Musalam 1997). AMP grazed pastures have been shown to have both lower soil temperature and higher moisture than conventionally grazed pastures, theoretically owing to increased soil biological activity that results in improved soil physical properties that increase water holding capacity and decreased bare ground (Dowhower et al. 2020). This indicates that AMP grazing can increase coprophagous arthropod abundance, potentially through the mechanism of a slower dehydration rate of dung provided from plant community structure. Consequently, this study has shown that AMP grazing has either a neutral or a positive effect on key beneficial functional groups throughout the different sampled arthropod communities, which may lead to the provision of ecosystem services to ranchers.

Implications

This study shows AMP grazing is a plausible tool to increase arthropod diversity without increasing pest abundance in the pasture habitat. Increased abundance of predators and parasitoids in the AMP foliar and soil arthropod community guilds (Fig. 4) are likely contributors of pest control in the AMP pastures. This is an ecosystem service for ranchers implementing an AMP grazing strategy. Furthermore, research conducted simultaneously with our study on the same pasture sites found that AMP grazing contributes additional benefits to ecosystem services and functionality, including, increased plant diversity and vegetation biomass, higher water infiltration rates, increased soil microbial diversity, and improved soil carbon levels (Mosier et al. 2021; Apfelbaum et al. 2022; Johnson et al. 2022). These findings indicate that AMP grassland systems have increased ecosystem functionality that returns ecosystem services to ranchers. It is important to continue to study the effects of AMP grazing on arthropods, especially over multiple grazing seasons, to better understand the mechanisms driving changes in arthropod communities in AMP managed pastures and to determine if these results stand the test of time. As our understanding of the ecological mechanisms that underpin the ability of AMP grazing to improve ecological functions in grasslands, we will be better able to harness the potential of AMP grazing to be used as a tool for biodiversity conservation in one of the largest ecosystems on the planet.

Data Accessibility

Data of foliar, soil, and dung arthropod communities is available as Supplementary Information in Schmid et al. 2021. An inventory of foliar, soil, and dung arthropod communities in pastures of the southeastern United States. doi:10.1002/ece3.7941.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rama.2024.03.001.

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