

An inventory of the foliar, soil, and dung arthropod communities in pastures of the Southeastern United States

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Abstract

Grassland systems constitute a significant portion of the land area in the U.S., and as a result, harbor a significant amount of arthropod diversity. During this time of biodiversity loss around the world, bioinventories of ecologically important habitats serve as important indicators for the effectiveness of conservation efforts. We conducted a bioinventory of the foliar, soil, and dung arthropod communities in 10 cattle pastures located in the southeastern U.S. during the 2018 grazing season. In sum, 126,251 specimens were collected. From the foliar community, 13 arthropod orders were observed, with the greatest species richness found in Hymenoptera, Diptera, and Hemiptera. The soil-dwelling arthropod community contained 18 orders. The three orders comprising the highest species richness were Coleoptera, Diptera, and Hymenoptera. Lastly, 12 arthropod orders were collected from cattle dung, with the greatest species richness found in Coleoptera, Diptera, and Hymenoptera. Herbivores were the most abundant functional guild found in the foliar community, and predators were most abundant in the soil and dung communities. While bioinventories demand considerable time, energy, and resources to accomplish, the information from these inventories has many uses for conservation efforts, land management recommendations, and the direction of climate change science.

Introduction

Biodiversity declines are a significant consequence of the Anthropocene (Dirzo et al. 2014, Johnson et al. 2017, Wagner 2020). Major drivers of change in biological community composition during the Anthropocene include habitat loss (Marini et al. 2012), climate change (Andrew et al. 2013), and agriculture intensification (Tscharntke et al. 2012). Arthropod communities are not immune to these effects, experiencing the largest population fluctuations in recorded history, with steep declines of many functional groups (Hallmann et al. 2017, Leather 2018, Lister and Garcia 2018, Sánchez-Bayo and Wyckhuys 2019, Wagner 2020). As these drivers of biological community change do not appear likely to abate in the near future, vigilant monitoring of arthropod communities is essential for facilitating conservation efforts and stemming biodiversity declines. Inventories of biological communities (bioinventories) provide vital records for future assessments of biodiversity fluctuations as the Anthropocene continues.

Rangeland/pasture systems constitute > 413 million acres in the U.S., comprising [?]22% of the contiguous U.S. landmass (NASS 2017). Owing to the large footprint of pastures on the terrestrial landscape, management decisions made in pasture systems have important implications for arthropod diversity (Wallis De Vries et al. 2007, Jerrentrup et al. 2014). Historically, pastures once hosted robust arthropod communities (Walkden and Wilbur 1944, Rottman and Capinera 1983), providing refuge from intensively managed cropland in regions of the U.S. (Schmid et al. 2015). The diversity of flora in pastures provides a strong resource base and a wide variety of ecological niches for arthropod communities, making these grazed grasslands important reservoirs of arthropod biodiversity, in addition to their uses in supporting agricultural production (Dennis et al. 1998, Morris 2000, Wallis De Vries et al. 2007). The vegetation alone provides a diversity of microclimates, pollen, seeds, nectaries, and vegetation that attract a myriad of arthropods (Lundgren

2009). Arthropods inhabiting grassland ecosystems fulfill needed ecological functions to maintain ecosystem stability and productivity for livestock production (Whiles and Charlton 2006, Joern and Laws 2013). In the southeastern U.S. bioinventories of arthropods in pasture systems have been relegated to surveys of economically important insect groups (e.g., dung beetles, red imported fire ants, ticks, pest flies, etc.), while being confined to small regions or states (Wilson 1963, Kramer et al. 1985, Fiene et al. 2011, Kaufman and Wood 2012, Pompo et al. 2016, Steele 2016). Consequently, arthropod assemblages in pastures of the Southeast region of the U.S. remain poorly described. This inventory would not only serve livestock producers in the region, but also serve as an important bioinventory reference during this pivotal time of global arthropod declines. In this study, the arthropod community and functional guilds of foliar, soil, and dung arthropod communities found in Southeastern U.S. pastures are described.

Methods

Study sites. Arthropod communities were sampled from pastures ($n = 10$) located in four states of the Southeastern U.S.: Kentucky ($n = 2$), Tennessee ($n = 2$), Alabama ($n = 4$), and Mississippi ($n = 2$) (Figure 1). Sampling the foliar and soil arthropod communities occurred three times during the 2018 grazing season (May 1 – 4, July 23 – 28, and Sept. 29 – Oct. 3), while dung community samples were collected only during the July and September sampling dates. Grazing systems had been practiced on pastures for at least 10 years prior to this study, but specific cattle management practices varied amongst pastures.

Sampling procedure. Two sampling areas were established in each pasture, with each sampling area containing three transect lines (45.7 m), for a total of six transects per pasture. The transects within a sampling area were parallel to one another and spaced 15.2 m apart.

Foliar-dwelling arthropods were sampled from pasture foliage at the 22.9 m mark of each of the three transect lines from the first sampling area in each pasture ($n = 3$ sweep samples/pasture). Vegetation was swept with a 38 cm diameter net, with 25 sweeps occurring perpendicular to each side of a transect line (total of 50 sweeps per transect). All arthropods collected from individual sweep samples were stored in plastic bags containing 3 mL of 70% isopropyl alcohol to preserve and prevent specimens from cannibalism. Samples were kept on ice in the field and returned to the lab, where they were stored at -18°C until arthropod specimens could be separated from loose vegetation in the sample. After which, specimens were preserved in 70% isopropyl alcohol for curation.

Core sampling (10 cm diameter, 10 cm deep) was used to collect the soil and dung communities. Cores were extracted at 7.6 m and 38.1 m on two of the transect lines for soil arthropod community sampling ($n = 8$ soil cores/ranch). Dung arthropod community cores were taken from the center of randomly selected dung pats found within the pasture borders ($n = 5$ dung cores/ranch). Age of dung pats ranged from 2 – 5 days old, as this age of pat has peak arthropod abundance and diversity (Pecenka and Lundgren 2018). All cores were kept cool on ice upon extraction from the field until they could be returned to the laboratory (60 h). Once in the laboratory, soil and dung cores were subjected to a Berlese funnel extraction system for 7 d, which ensured each soil/dung core had completely dried and all arthropods had evacuated from the core. Arthropods extracted from cores with the Berlese system were stored in 70% isopropyl alcohol, until they could be identified and cataloged.

Community composition. To characterize the arthropod communities, each specimen from the foliar, soil, and dung samples was identified to the lowest taxonomic level possible. Due to 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, nor springtails (Hexapoda: Collembola) beyond the family level. All other specimens were separated to genus or species level. Those for which positive species identifications could not be provided were assigned to a numbered morphospecies. Larvae of holometabolous insects were considered as distinct morphospecies, owing to their discrete differences in ecological function. Morphospecies were assigned to functional guilds, based on knowledge and current hypotheses regarding the ecology of these organisms. We recognized nine non-exclusive guilds: 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).

Results

Foliar arthropod community. In total, 52,128 arthropod specimens were collected from pasture foliage, representing 759 morphospecies from four classes (Arachnida, Collembola, Insecta, and Symphyla) and 13 orders (Araneae, Coleoptera, Diptera, Entomobryomorpha, Hemiptera, Hymenoptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Psocoptera, Symphyleona, Thysanoptera). A complete list of foliar arthropod specimens and their abundance from this study can be found in the Supporting Information accompanying this article. The five orders that contained the highest number of morphospecies and specimen abundance are listed in Table 1. Ecological guilds of the foliar arthropod community consisted predominately of herbivores, parasitoids, and predators (Figure 2A, B). Only 1.84% of the morphospecies and 1.01% of the specimen abundance were pests (Figure 3A, B).

Soil arthropod community. A total of 224 soil cores were extracted for this study to examine the soil dwelling arthropod community. In sum 53,292 arthropod specimens were extracted from the soil, representing 436 morphospecies from eight classes (Arachnida, Chilopoda, Collembola, Diplopoda, Diplura, Insecta, Protura, and Symphyla) and 18 orders (Araneae, Coleoptera, Dicellurata, Diptera, Dermaptera, Entomobryomorpha, Geophilomorpha, Hemiptera, Hymenoptera, Julida, Lepidoptera, Lithobiomorpha, Neuroptera, Opiliones, Orthoptera, Psocoptera, Symphyleona, Thysanoptera). A complete list of soil arthropod specimens and their abundance from this study can be found in the Supporting Information accompanying this article. The five orders containing the highest number of morphospecies and specimen abundance are listed in Table 1. Examining the known functional guilds of arthropod morphospecies shows predators comprised the largest portion of the community followed by herbivores and parasitoids (Figure 2C). Predators also comprised the largest functional guild of known arthropod abundance followed by granivores and herbivores (Figure 2D). Pest species constituted only 2.25% of the morphospecies and 0.34% of the specimen abundance (Figure 3C, D).

Dung arthropod community. A total of 100 dung pats were subjected to core sampling. In sum, 20,831 specimens, representing 234 morphospecies from six classes (Arachnida, Chilopoda, Collembola, Diplura, Insecta, and Symphyla) and 12 orders (Araneae, Coleoptera, Dermaptera, Dicellurata, Diptera, Entomobryomorpha, Hemiptera, Hymenoptera, Orthoptera, Psocoptera, Symphyleona, Thysanoptera). A complete list of dung arthropod specimens and their abundance from this study can be found in the Supporting Information accompanying this article. The five orders with the highest number of morphospecies and specimen abundance are listed in Table 1. Predators were the most speciose functional group, followed by parasitoids and herbivores (Figure 2E). Predators were also the most abundant of the functional guilds, followed by coprophages and granivores (Figure 2F). Only 2.47% of the morphospecies and 0.46% of the specimen abundance were pests (Figure 3E, F).

Discussion

Our survey shows an abundant and diverse arthropod community in pastures of the Southeastern U.S. In total, 126,25 specimens were identified to morphospecies for this survey, making it one of the largest assessments of arthropod diversity in pasture systems in the region. Previous surveys of arthropods in grazing lands of the Southeastern U.S. focused on specific groups of arthropods (e.g., pests, dung beetles, biocontrol agents, and pollinators), or on specific habitats within pastures (e.g., plant foliage or dung pats) (Wilson 1963, Kramer et al. 1985, Hu 1995, Pompo et al. 2016, Leppla et al. 2017). To our knowledge, our bioinventory is one of the most comprehensive surveys of arthropod communities in pastures of the Southeastern U.S., including foliage, soil and dung microhabitats. Furthermore, this bioinventory identified the majority of collected arthropods to the family level. The magnitude and comprehensive identification of specimens from our bioinventory will serve as a valuable reference for future biodiversity studies.

Our bioinventory shows both similarities and differences in community composition compared to previous studies conducted in the region. For example, a survey of dung-dwelling arthropods in north-central Florida found the orders with the highest species richness to be Coleoptera (109 species), Diptera (35 species), and Hymenoptera (24 species) (Hu 1995), while our study found a similar pattern of species richness in the dung community with Coleoptera (105 species), Diptera (53 species), and Hymenoptera (40 species). The higher number of Diptera and Hymenoptera species reported by our study relative to Hu (1995) may be the result of the larger geographic range conducted by our survey. Another example of arthropod bioinventories in grasslands of the Texas panhandle found the canopy-dwelling to have the highest specimen abundance in the orders of 1) Hemiptera, 2) Araneae, 3) Orthoptera, 4) Coleoptera, and 5) Hymenoptera (Bhandari et al. 2018). These results differ from our survey, which documented the five most abundant orders to be 1) Hemiptera, 2) Diptera, 3) Hymenoptera, 4) Orthoptera, and 5) Araneae. While Hemiptera tops the list of both bioinventories, the remainder of the orders differ between the two inventories. The differences in arthropod abundance between the inventories could be for a multitude of reasons, e.g., time of sampling, grassland management, surrounding landscape, etc. One likely mechanism that contributed to the differences between inventories was variances in grassland habitat between the two distant geographic locations, i.e., the Southern Great Plains versus the Southeastern U.S. The results of previous arthropod bioinventories relative to our bioinventory highlights the differences that exist in arthropod communities from similar habitats but different geographic locations. This information underpins the need for future arthropod inventories from various habitats and different regions as a means to accurately assess biodiversity declines during the Anthropocene.

The assemblage of functional guilds was distinct amongst the three arthropod communities sampled for this study (Figure 2). To begin, herbivores were the most abundant guild in the foliar community, while predators were the most abundant guild in the soil and dung communities. The high abundance of herbivores in the foliar community is not surprising, as herbivores are often the most abundant group found in plant canopies of grasslands (Cagnolo et al. 2002, Hironaka and Koike 2013). However, the relatively low abundance of pollinators in the foliar community was unexpected to us. But this result does align with a recent rangeland bioinventory, which documented pollinators to be only a minor portion of the community (Bhandari et al. 2018). The abundance of pollinators in pasture systems is likely influenced by forb abundance. Consequently, the small number of pollinators may be a result of pasture management that prioritizes production of grasses over forbs for cattle production. Although grass production is the primary concern of ranchers raising cattle, a balanced cattle diet includes forbs (Grant et al. 1985). Thus, increasing the abundance of forbs in pastures could improve pollinator abundance, while also fulfilling cattle dietary requirements. Unlike the foliar community, the soil and dung communities were dominated by predatory arthropods. Due to the lack of experimental manipulation in the design of this study, it is difficult to ascertain why predators were the most abundant group in the soil and dung. However, it should be noted that a significant portion of the collected specimens were classified as unknown in terms of functional guild. We hypothesize that many of the unknown arthropods in our survey constituted food sources for the predator population, helping to support the large predator portion of the community. We hypothesize many of the unknown specimens are detritovores, but lacking creditable sources to classify these specimens. It is also worth noting that pest species comprised a very small portion of the arthropod community in all three habitats, comprising only 1.01%, 0.34%, and 0.46% of arthropod abundance in the foliar, soil, and dung habitats, respectively. The predators combined with competition from other specimens of other functional guilds seem to be capable of holding pest populations in check in these pasture systems. Further studies are needed to better understand life histories of many of the organisms and further our understanding of arthropod food webs in pasture ecosystems.

Describing arthropod communities of various habitats and agriculture systems requires further attention in order to provide meaningful data for future studies (Goldstein 2004, Apfelbaum and Haney 2012). For instance, bioinventories of pastures can inform land managers and government agencies about livestock and land management practices that promote conservation efforts of endangered species or guilds of conservation interest, e.g., rusty-patch bumblebee or pollinators. Furthermore, bioinventories serve as reference points to

compare shifts in community composition as novel pasture management methods are tested. Perhaps most importantly, bioinventories serve as a reference during biodiversity declines of the Anthropocene. Without bioinventories, we are essentially flying blind during this time of biodiversity loss. Leaving us unable to make informed decisions to conserve at risk species. While bioinventories demand considerable time, energy, and resources to accomplish, they are vital for the future of biodiversity on our planet, and their value cannot be overstated.

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Data accessibility

Upon acceptance to Ecology and Evolution, data will be archived on Dryad and DOI will be included with this manuscript.

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Table 1. Arthropod orders with the highest number of species richness (morphospecies) and abundance of specimens collected (abundance) in foliar, soil, and dung habitats. Arthropods communities were collected from cattle grazed pastures (n = 10) in the southeastern US from May – October 2018.

		Morphospecies	Morphospecies	Morphospecies	Abundance	Abundance
Foliar	1)		Hymenoptera	194	Hemiptera	17,601
	2)		Diptera	163	Diptera	11,440
	3)		Hymenoptera	155	Hymenoptera	3,386
	4)		Coleoptera	105	Orthoptera	2,831
	5)		Araneae (spiders)	55	Araneae (spiders)	1,924
Soil	1)		Coleoptera	172	Hymenoptera	7,105
	2)		Diptera	100	Hemiptera	2,500
	3)		Hymenoptera	54	Coleoptera	1,503
	4)		Hemiptera	53	Diptera	1,075
	5)		Araneae (spiders)	23	Araneae (spiders)	201
Dung	1)		Coleoptera	102	Coleoptera	3,215
	2)		Diptera	53	Hymenoptera	1,456
	3)		Hymenoptera	37	Diptera	1,342
	4)		Hemiptera	13	Hemiptera	544
	5)		Araneae (spiders)	5	Araneae (spiders)	31

Figure 1. Pastures (n = 10) sampled for this study were located in Allen County, KY; Marion County, TN; DeKalb County, AL; Calhoun County, AL; and Wilkinson County, MS. Counties where sampling occurred are highlighted in black on state county maps.

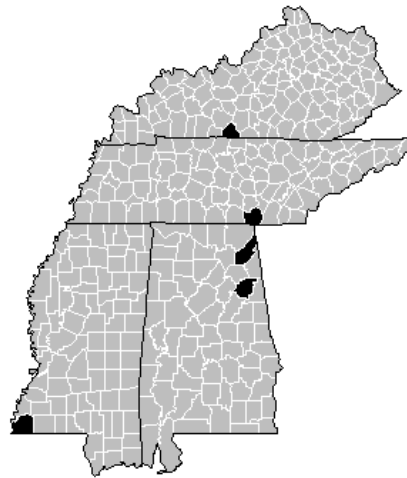


Figure 2. Functional guilds of arthropod species richness and specimen abundance for foliar (A, B), soil (C, D), and dung (E, F) communities. Arthropod communities were sampled from pastures (n = 10) grazed by cattle in the southeastern US.

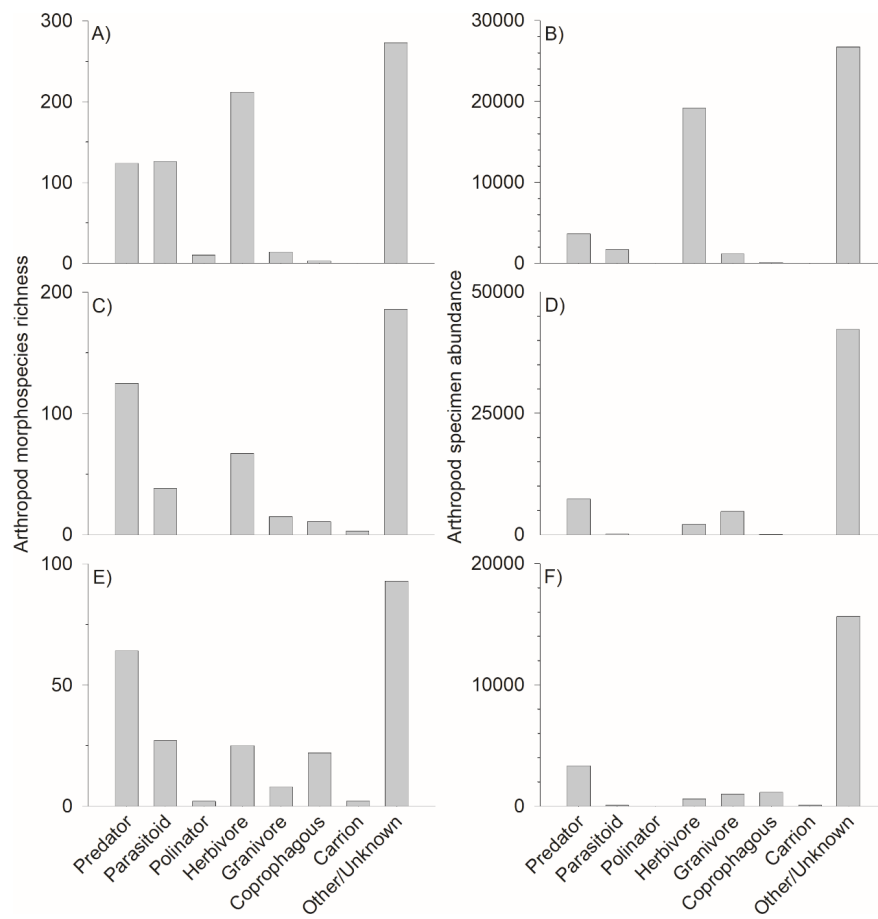


Figure 3. Abundance of pest species in terms of morphospecies and specimens collected from foliar, soil, and dung arthropod communities. Arthropods were collected from cattle grazed pastures ($n = 10$) in the southeastern US.

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