ABSTRACT

Title of Thesis:	AGRICULTURAL DRAINAGE DITCHES AS SOURCES OF BENEFICIAL SPIDERS TO ENHANCE CONSERVATION BIOCONTROL IN ADJACENT CROPLANDS
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Agricultural drainage ditches are uncropped areas on farms located above high-water tables to assist in the hydrologic control of croplands. Drainage ditches have increasingly become the subject of research as sources of beneficial arthropods for agroecosystems. Spiders, the most common generalist predator in most field crops, are an important component of conservation biocontrol, but little is known of spider assemblages in drainage ditches or the extent they colonize adjacent croplands from these ditches. To better understand the composition and population dynamics of spider assemblages in drainage ditches, my objectives were (1) to assess the structure of spider assemblages inhabiting drainage ditches in Maryland and (2) to determine how spider assemblages in drainage ditches and adjacent soybean fields change throughout the soybean growth cycle. Overall, my work contributes to understanding how valuable drainage ditches are as habitats for natural enemies like spiders and how ditches influence spider assemblages in adjacent croplands.

AGRICULTURAL DRAINAGE DITCHES AS SOURCES OF BENEFICIAL SPIDERS TO ENHANCE CONSERVATION BIOCONTROL IN ADJACENT CROPLANDS

by

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Dedication

To Archibald and Morrigan von Whiskers

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Abstract

Ecological intensification has recently been suggested as a method to reduce agricultural inputs and enhance ecosystem services to support increasing crop demands. Agricultural drainage ditches, which are common structures on farms along Maryland’s Eastern Shore, are typically used to provide hydrological control for croplands located above high-water tables. However, these uncropped strips of land which intersect or border croplands have received little attention regarding the potential ecosystem services they could provide. Spiders, the most abundant generalist predator in agroecosystems, are a major contributor to the estimated $4.5 million in pest suppression provided by natural enemies in agroecosystems. Spider assemblages in drainage ditches have not previously been examined for their community structure or for what factors influence spider communities. To better understand the pattern of spider communities in the drainage ditch ecosystem, my research objectives were: (1) to identify the taxonomic diversity and abundance of spiders present in agricultural drainage ditches, and (2) to discern environmental characteristics of the drainage ditch ecosystem related to spider diversity and abundance. I collected spiders from 15 drainage ditches during three summer months in 2017 by sweep netting and ground litter collection across Maryland’s Eastern

Shore along with ditch plant diversity and environmental condition data. I found that drainage ditches contain robust spider communities (14 families, 25 genera) and that the most common spiders in drainage ditches belong to *Oxyopes* (Oxyopidae), *Maevia* (Salticidae), *Pachygnatha* (Tetragnathidae), and *Tetragnatha* (Tetragnathidae). Spider communities were most abundant and diverse in late May/early June and decreased in abundance and diversity as the summer progressed. The plant diversity and physical characteristics of drainage ditches did not explain spider diversity and abundance trends, which are instead better explained by movement due to habitat conditions and spider phenology.

Introduction

Ecological intensification is the practice of replacing anthropogenic strategies to enhance crop productivity by supporting ecosystem service management in agroecosystems (Bommarco et al. 2013). The concept of ecological intensification was put forth to address the loss of natural enemies brought on by recent increases in global agricultural intensification (Tscharntke et al. 2012). Ecological intensification has been suggested as a method to enhance the ecosystem services necessary to achieve ever-increasing global demand for crops (Gaba et al. 2014). Ecological intensification is achieved by modifying the agricultural landscape to enhance ecosystem services, or by preserving existing habitats that already support beneficial arthropods (Geertsema et al. 2016, Blake et al. 2013). In many cases, most important ecosystem services such as pollination or pest suppression in agroecosystems are performed predominantly by arthropods (Swinton et al. 2007). Identifying sources of ecosystem services in agricultural settings requires thorough investigation of potential habitats that may support beneficial arthropods. Of all the habitats assessed for their value as sources of ecosystem services, here I focus on agricultural drainage ditches which have received increasing attention regarding their potential to enhance ecosystem services (Herzon and Helenius 2008).

Agricultural drainage ditches are created to provide hydrological control for croplands with high water tables to maintain water levels and prevent flooding (Needelman et al. 2007). The areas in which drainage ditches are constructed varies according to the geomorphology of the land surrounding and within the croplands. As a result of this variation, drainage ditches are constructed along the margins of croplands or directly intersect croplands depending on groundwater flow regimes. Drainage ditch systems for croplands are typically constructed so that multiple drainage ditches flow into a collection ditch, which carries the excess water away from croplands to an outlet, such as a nearby stream, river or lake. Drainage ditches vary in physical characteristics, such as width and depth, temporary or permanent flow of water, and in their management by farmers, which can influence the presence of fauna and flora in any given ditch. While federal guidelines exist on how often drainage ditches should be cleared of vegetation or dredged to prevent sedimentation buildup over time, these guidelines do not discuss how to maintain drainage ditches to enhance ecosystem services. Uncropped areas surrounding croplands, such as hedgerows and field margins, already have evidence to suggest that they may serve as a refuge for beneficial arthropods during periods when nearby croplands are unsuitable for habitat, such as after harvests or cultivation events (MacLeod et al.

2004, Oberg et al. 2007). Drainage ditch habitats are widely considered to be refugia for species of importance regarding ecosystem services in Europe, but little is known of their diversity in the United States (Herzon and Helenius 2008). Thus, drainage ditches across Maryland may also serve as refugia for natural enemies in agroecosystems.

Of the beneficial arthropods that could support ecological intensification, generalist predators have long been considered for their applications for pest suppression and stabilization, but little research exists on their sources in agroecosystems (Ferguson et al. 1984, Mansour et al. 1983, Symondson et al. 2002). Spiders, the most common generalist predator in agroecosystems, far surpass other generalists such as carabid beetles and reduviid bugs in both diversity and abundance in croplands (Rand 2017). Previous studies on spider predation estimate that 400-800 million tons of prey are killed each year by the global spider community, with 3 trillion individual prey organisms consumed in croplands alone (Nyffeler and Birkhofer 2017). The level of pest suppression provided by spiders has been considered by crop managers since antiquity, when ancient Chinese farmers would actively attempt to preserve spider abundance in croplands by placing straw mounds in freshly harvested croplands to retain some habitat structure for spiders to inhabit during the off-season (Halaj et al. 2000). In modern times, high spider abundance has been associated with reduced herbivore damage in field crops such as soybeans and rice (Carter and Rypstra 1995). The diversity of the spider community is likely to vary among ditches which reflect variable opportunities for pest predation by spiders (Nyffeler and Birkhofer 2017). While all spiders are predators, their behavior and morphology differ in how they capture prey and can be grouped into functional feeding guilds (Uetz et al. 1999). Each spider functional feeding guild has been fine-tuned through evolutionary time to excel at capturing prey in specific habitats and situations that often times do not overlap with other feeding guilds (Riechert and Lockley 1984). Thus, multiple spider functional feeding guilds can exist in one habitat, which in turn increases the potential of pest predation by spiders.

Spiders require two major resources to survive in their habitat: prey availability and appropriate habitat structure, such as web attachment sites for orb-weaving spiders or camouflage for ambushing or stalking spiders. (Uetz et al. 1999). Habitat structure for spiders includes specific habitat structures to optimally employ their feeding strategies, such as proper space and attachment sites for spider webs or niches for retreats and ambush sites (Uetz et al. 1978, Toft 1987). The necessary habitat structures varies across spider functional feeding groups. Spiders that acquire prey through the “wandering” feeding strategy may be less impacted by the structural conditions in their habitat, while web-weaving, ambushing and stalking spiders may be unable to acquire prey if local habitat structure doesn’t support these strategies (Uetz et al. 1978). Due to the uncropped nature of agricultural drainage ditches, ditch habitats are likely to be more structurally diverse than the adjacent croplands, which in turn can support increased functional feeding guild diversity in drainage ditches compared to croplands.

This study was inspired by recent interest in ecological intensification, which has been suggested as a strategy to enhance ecosystem services while reducing inputs in agroecosystems. Drainage ditches have previously been studied for their biological importance as a result of them possessing unique biological communities relative to agricultural landscapes (Herzon and Helenius 2008). Ditches may provide ecosystem services like pest suppression by natural enemies to croplands, as drainage ditches are less disturbed, uncropped areas typically intersecting or closely located near croplands. However, due to the variety of farm management practices used among farms, as well as the colonization of ditches by plant species, spider biodiversity is likely to differ among ditches. In this chapter of my thesis, I aimed to describe the diversity and abundance of spider assemblages in Maryland drainage ditches and identify potential environmental influencers of these communities. Specifically, my research objectives for this chapter were (1) to characterize the diversity and abundance of spider assemblages in drainage ditches, (2) assess how spider assemblages in drainage ditches differ between ditches and change as the summer progresses (3) assess how plant assemblages and the physical characteristics of drainage ditches influence the spider assemblages living within them.

Methods

Farm and drainage ditch selection

I surveyed agricultural drainage ditches located within croplands that represented a range of farming practices and environmental conditions on the Delmarva Peninsula, Maryland. Three drainage ditches were selected from each of five farms, for a total of 15 drainage ditches. All farms will be referenced by codenames for the sake of the privacy of farms and landowners. Three farms were selected in Queen Anne's County (Farm codenames HOW, MAS and WYE), one farm in Wicomico County (Farm codename COOP) and one farm in Somerset County (Farm codename UMES). Farms UMES and WYE were both university affiliated farms that practiced conventional agriculture, while Farms MAS, HOW, and COOP all practiced organic crop management strategies. Each ditch was sampled over three dates: Wicomico/Somerset county farms on May 31st, July 5th and August 16th, 2017; Queen Anne's county farms were sampled on June 1st, July 6th and August 17th, 2017. Two 30m reaches along each ditch were flagged for sampling, with 15m of this reach dedicated to sweep sampling, while the other 15m was used for ground litter and plant collections. All collections were conducted in 10-minute timed sampling periods for each reach of each ditch, in order to rapidly assess as many drainage ditches as possible during the summer sampling season.

Spider sampling in drainage ditches

At each drainage ditch, spiders were collected through foliar sweeping and ground litter sampling. Foliar sweep sampling was conducted with a 38cm hoop sweep net at two locations at each drainage ditch: the bank top of the ditch and the ditch's slope side. Each sweep sample at each location encompassed a 15-meter reach of the drainage ditch, comprised 100 sweeps, with each sample being frozen and later hand-picked of spiders under a dissecting microscope. Two 30 meter reaches with the drainage ditch were sampled each sampling day using this sweeping protocol, the contents of which were later combined for use in statistical analysis. In order to collect ground dwelling spiders, each side of each drainage ditch in the 15m reach set aside for plant collections, all vegetation over 5cm height was cleared using electric clippers within a 50x50cm frame, after which the dead plant debris beneath the freshly cut foliage was collected with a gardening trowel and placed in 950-mL SOLO® paper containers. Two ground litter samples were collected from each side of each ditch on each sample date: one from the ditch bank and the other from the ditch slope. All ground litter samples stored in paper cans were later processed using Berlese funnels, which use a light source to push arthropods hiding in plant debris into ethanol-filled jars, to remove cryptic spiders and arthropods. All spiders collected in drainage ditches were identified to genus (Ubick et al. 2017).

Plant and environmental conditions

The environmental conditions of each drainage ditch sampled were measured concurrent to spider collections on each sampling day. Each drainage ditch was measured for various physical characteristics, such as width, depth, wetted width, wetted depth, and observable water flow. Ditch width was measured from bank top to bank top using a 100m tape measure. Ditch depth was measured from the top of the bank to the bottom of the ditch using meter sticks. Observable water flow was determined visually at each ditch during each sampling period. Plant diversity and coverage was assessed using the Daubenmire cover class method (Daubemire 1959). Cover classes for plant genera at each ditch were recorded for 10 Daubenmire 20x50cm frames for the ditch bank top. Unknown plant specimens were collected in plastic bags and pressed in the laboratory for later identification.

Statistical analysis

All statistical analyses were performed in SAS Studio (2019). Spider abundance and spider taxa richness collected from the bank-top and ditch slope areas in drainage ditches by performing one ANOVA for each sampling period (June, July and August). To determine the similarity of the spider assemblages in the drainage ditches, we performed a Bray-Curtis hierarchical cluster analysis, creating a Bray-Curtis dissimilarity matrix using PROC DISTANCE and then performing the cluster analysis through PROC CLUSTER. Two Bray-Curtis dissimilarity cluster analyses were performed using this method: one generating the matrix from the abundance of spiders in each genus, the other creating a matrix from the abundance of spiders in each spider functional feeding guild. The physical characteristics of each drainage ditch, along with plant taxa richness and plant Shannon diversity were then compared for each ditch cluster to detect any clustering variables. The plant assemblages in drainage ditches were ranked by their relative abundance to illustrate the diversity and evenness of the plant assemblages within each drainage ditch at each sampling date.

Results

Physical characteristics of drainage ditches

The physical characteristics of drainage ditches varied greatly from ditch to ditch (Table 1.1). Ditch width ranged from 3.0 to 6.6m wide, while ditch depth ranged from 0.5m to 2.5m deep. Wetted ditch width and depth also varied greatly, with most ditches providing no observable flow during all three sampling periods. Generally, drainage ditches located within the same farm were similar in their physical characteristics, aside from the UMES drainage ditches, which were not all owned and managed by the same agricultural organization. Water flow was only observed at 4 drainage ditches across any sampling period, with 3 of the drainage ditches all located at the same farm.

Table 1.1 Physical characteristics measured at each drainage ditch during summer 2017.

Farm Information			GPS location		Ditch size		Channel measures		
County	**Farm**	**Ditch**	**North**	**East**	**Width (m)**	**Depth (m)**	**Wetted Width (cm)**	**Wetted Depth (cm)**	**ObservedFlow**
Somerset	UMES	VTPoll	N38.21343°	W75.67019°	3.6	0.5	35	1	N
Somerset	UMES	CornPepper	N38.21124°	W75.67072°	4.0	0.7	180	3	N
Somerset	UMES	Palmetto	N38.22432°	W75.64529°	6.6	2.0	120	15	Y
Wicomico	COOP	East	N38.32633°	W75.71615°	3.6	1.3	100	33	N
Wicomico	COOP	West	N38.32693°	W75.71713°	3.6	1.1	100	30	N
Wicomico	COOP	South	N38.32390°	W75.71815°	3.6	1.2	75	5	N
QueenAnne	WYE	West	N38.91471°	W76.15316°	4.8	0.1	180	1	N
QueenAnne	WYE	East	N38.91751°	W76.14864°	3.8	0.1	0	0	N
QueenAnne	WYE	FieldPlot	N38.91624°	W76.14537°	3.6	0.9	0	0	N
QueenAnne	MAS	South	N39.01051°	W75.94491°	3.0	2.5	120	5	Y
QueenAnne	MAS	North	N39.01047°	W75.94492°	3.0	2.5	150	10	Y
QueenAnne	MAS	Field	N39.02124°	W75.95171°	6.0	2.0	90	10	Y
QueenAnne	HOW	North	N39.23917°	W75.86742°	4.6	0.6	260	8	N
QueenAnne	HOW	Phrag	N39.23880°	W75.86719°	4.6	0.6	260	8	N
QueenAnne	HOW	South	N39.23817°	W75.86892°	4.0	0.6	250	8	N

Spider diversity and abundance

A total of 249 spiders were collected from sweeps samples across all drainage ditches and sampling periods in 2017. During the June sampling, 55 spiders were collected from sweeps along ditch bank tops, while 80 spiders were collected along the ditch slopes. During the July sampling period, 31 spiders were collected from bank-top sweeps, while 34 were collected from ditch slope sweeps. During the August sampling period, 21 spiders were collected from bank-top sweeps while 28 were collected from ditch slope sweeps. No significant differences were found between the bank-top and ditch slope spider abundances collected during each sampling period, so these abundances were combined for each ditch within each sampling period for all other analyses in this chapter (ANOVA, F= 0.32, df=1, p=0.67). Of the juvenile spiders collected from sweep sampling, the June sampling period produced the most with 42 juvenile spiders, followed by the August sampling period with 30 juveniles and the July sampling period with 29 juveniles. For most drainage ditches, sweep samples taken during the June sampling period collected more spiders than the July or August sampling periods. Across the drainage ditches, sweep spider abundances varied greatly between drainage ditches, but in most cases were more similar between ditches located the same farm (Figure 1.1).

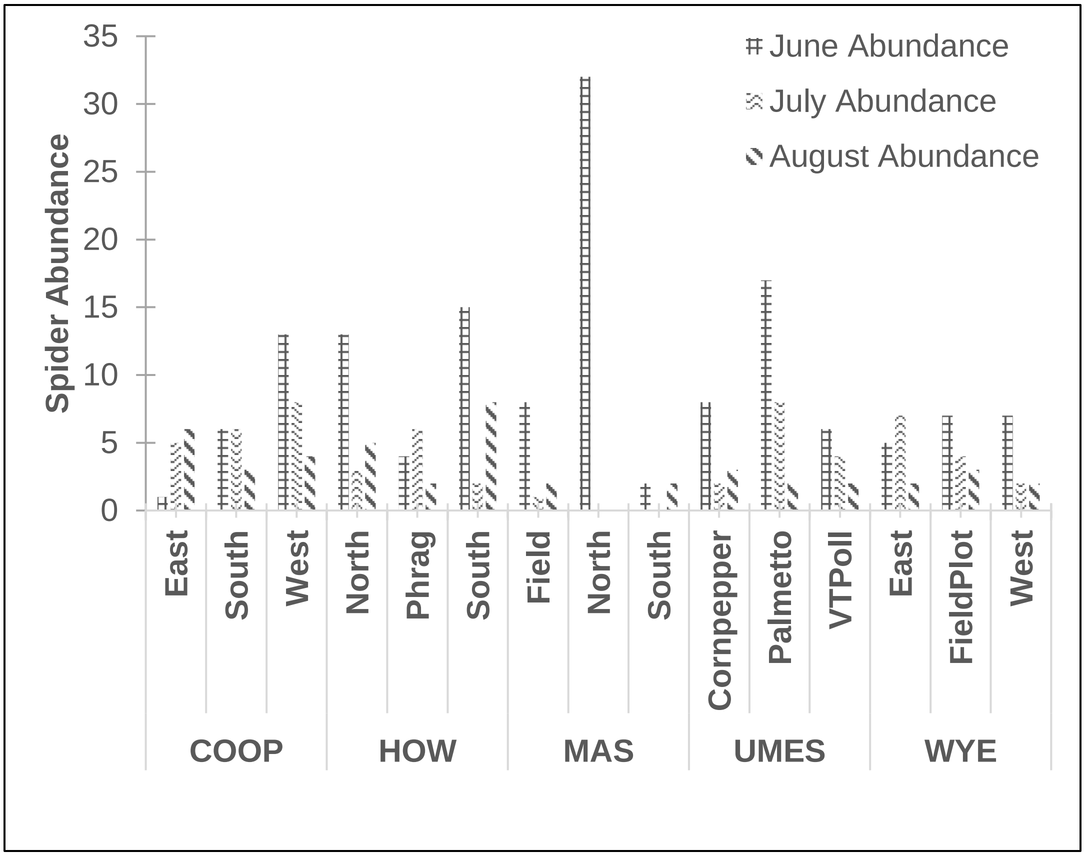

Figure 1.1 Total spider abundance collected from each ditch across each sampling period via sweep net sampling.

A total of 53 spiders were collected from litter samples across all drainage ditches and sampling periods in 2017. During the June sampling period, 4 spiders were collected from litter samples along ditch bank tops, while 2 spiders were collected along the ditch slopes. During the July sampling period, 10 spiders were collected from bank-top sweeps, while 11 were collected from ditch slope sweeps. During the August sampling period, 14 spiders were collected from bank-top sweeps while 12 were collected from ditch slope sweeps. No significant differences were found between the bank-top and ditch slope litter spider abundances collected during each sampling period, so these abundances were combined for each ditch within each sampling period for all other analyses in this chapter (ANOVA, F=0.68, df =1, p=0.56). Of the juvenile spiders collected from litter sampling, the August sampling season produced the most with 23 juveniles, followed by the July sampling period with 16 juveniles and the June sampling period with 6 juveniles. Overall, more juvenile spiders were collected from litter sampling than adult spiders. For most drainage ditches, litter samples taken during the August sampling period collected mores spiders than the July and June sampling periods. Across drainage ditches, litter spider abundance, like the sweep spider abundances, were more similar in abundance between drainage ditches located at the same farm than ditches at different farms (Figure 1.2). When comparing adult and juvenile spider abundances across the entire collection, we collected more spiderlings (167) than adult spiders (135), with the majority of juveniles also collected during the June sampling period (64).

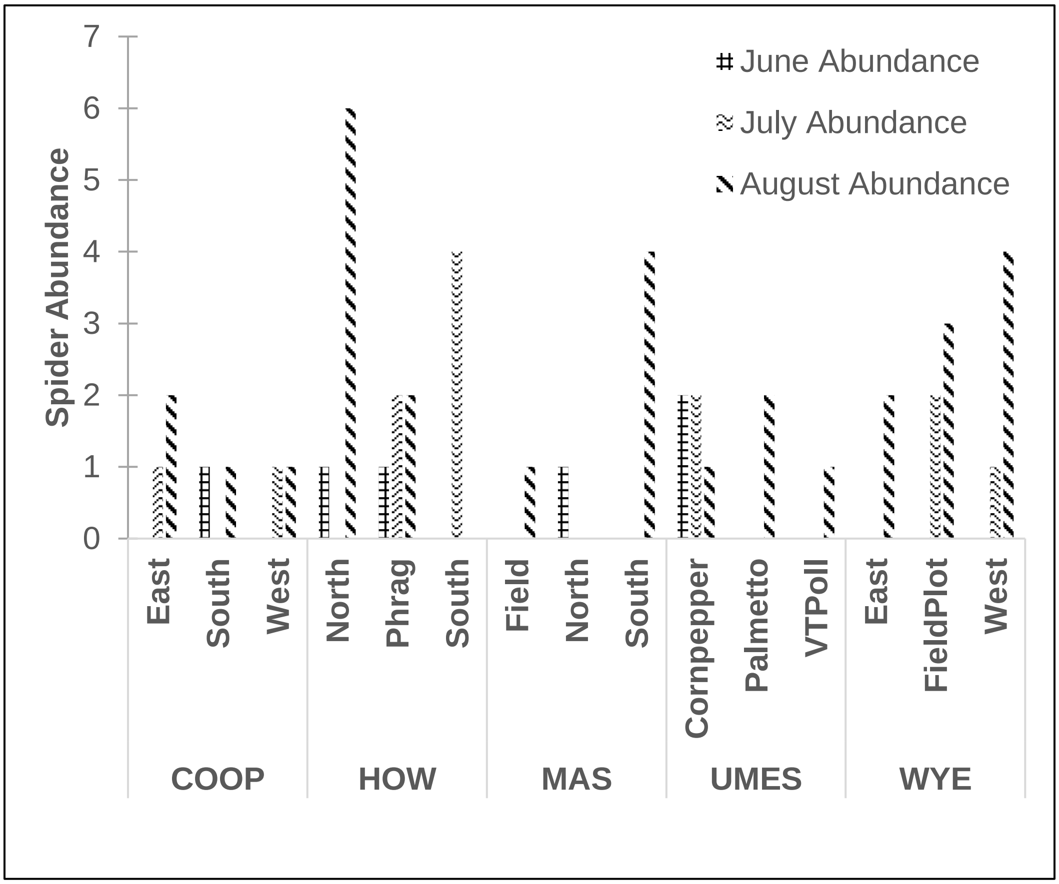

Figure 1.2 Total spider abundance collected from each ditch across each sampling period via ground litter sampling.

Fourteen spider families encompassing 25 genera were identified across all sampling methods and sampling periods (Table 1.2). The three most commonly identified spider genera during the 2017 sampling effort were *Oxyopes* (Family Oxyopidae) with 34 observed specimens, *Maevia* (Family Salticidae) with 25 specimens, and *Tetragnatha* (Family Tetragnathidae) with 18 specimens. It is worthy to note that linyphiid spiders were also in high abundance (54 spiders), but most were juveniles that could only be identified to family. Of the spiders collected from sweep sampling, the June sampling period produced the highest mean taxa richness of 4.4±2.7 genera identified across all drainage ditches. Mean spider taxa richness collected from sweeps declined as the summer progressed, with the July and August sampling periods producing an average of 2.8±1.7 and 1.8±0.7 taxa across all ditches (Figure 1.3). Of the spiders collected from litter sampling, mean taxa richness increased as the summer progressed with June, July and August producing 0.40±0.63, 1.0±1.0, and 1.1±0.7 mean taxa respectively (Figure 1.4).

Table 1.2 Spider families and genera identified from all drainage ditches and sampling dates during summer 2017. All individuals identified to genus were adult specimens, as juvenile specimens were only identifiable to family.

Family	Genus	FFG
Anyphaenidae	*Hibana*	Foliage Runner
Araneidae	*Araniella*	Orb Weaver
	Neoscona	Orb Weaver
	Larinioides	Orb Weaver
	Ocrepeira	Orb Weaver
	Unidentified Juvenile	Orb Weaver
Antrodiaetidae	*Antrodiaetus*	Burrowing
Atypidae	*Sphodros*	Burrowing
Linyphiidae	*Erigone*	Wandering Sheet Weaver
	Unidentified Juvenile	Wandering Sheet Weaver
Lycosidae	*Trochosa*	Ground Runner
	Unidentified Juvenile	Ground Runner
Oxyopidae	*Oxyopes*	Stalker
Philodromidae	*Philodromous*	Ambusher
	Tibellus	Ambusher
Pisauridae	*Dolomedes*	Ambusher
	Pisaurina	Ambusher
Pholicidae	*Pholcus*	Space Web Weaver
Salticidae	*Habronattus*	Stalker
	Maevia	Stalker
	Peckhamia	Stalker
	Sassacus	Stalker
	Unidentified Juvenile	Stalker
Tetragnathidae	*Pachygnatha*	Orb Weaver
	Tetragnatha	Orb Weaver
Theridiidae	*Parasteatoda*	Space Web Weaver
	Styopis	Space Web Weaver
	Unidentified Juvenile	Space Web Weaver
Theriodosomatidae	*Theridosoma*	Space Web Weaver
Thomisidae	*Bassaniana*	Ambusher
	Mechaphesa	Ambusher
	Misumessus	Ambusher
	Ozyptilla	Ambusher
	Xysticus	Ambusher
	Unidentified Juvenile	Ambusher

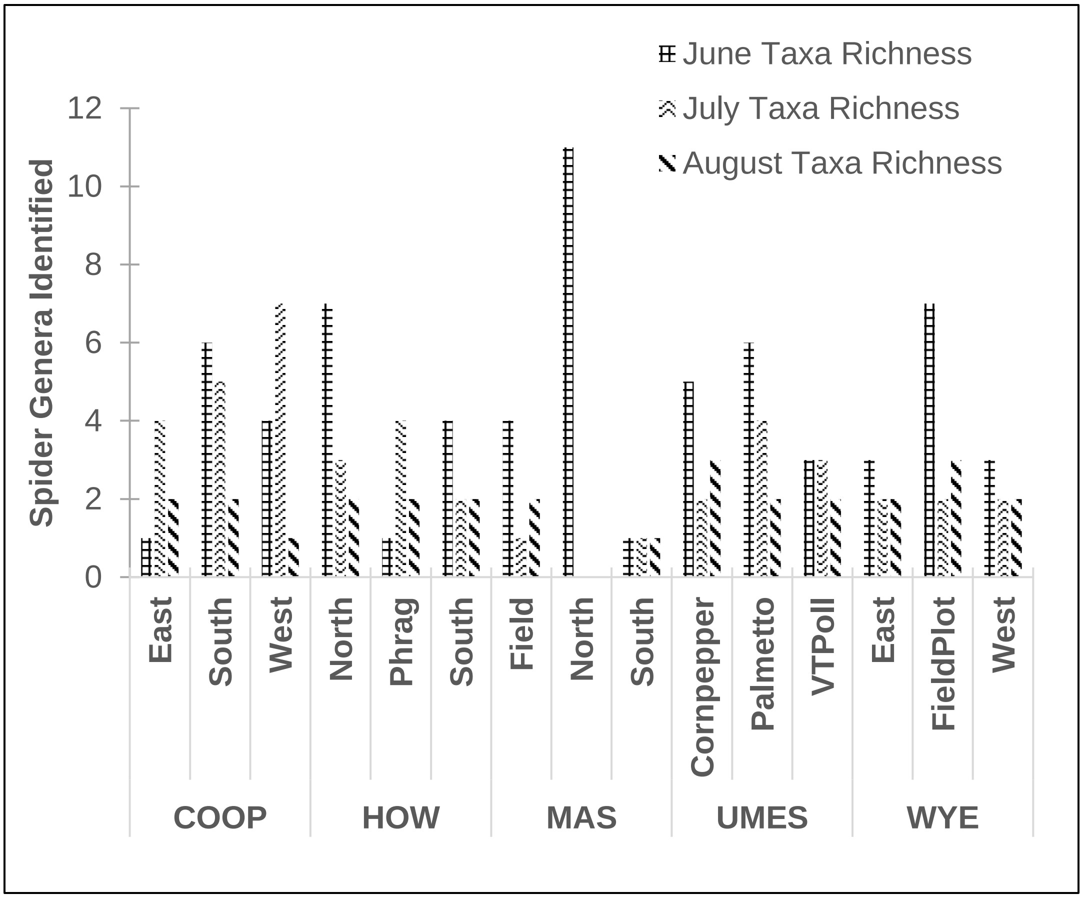

Figure 1.3 Spider taxa richness collected from each ditch across each sampling day via sweep sampling.

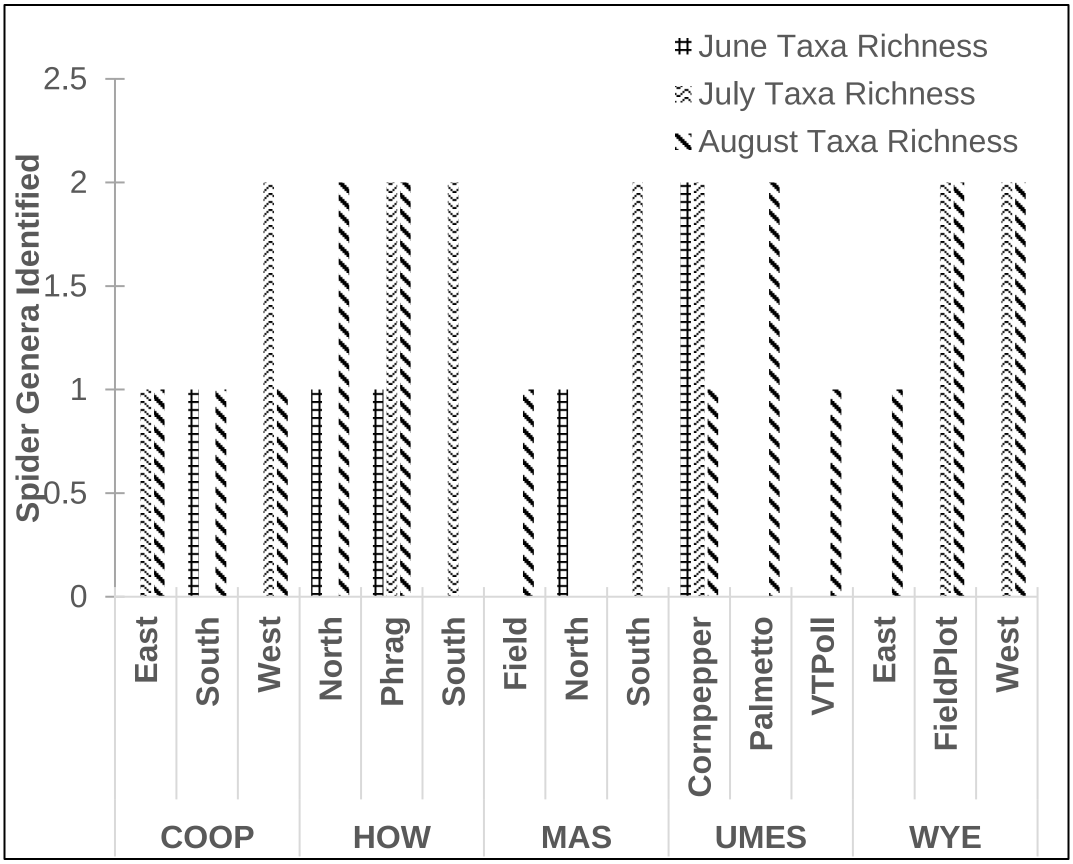

Figure 1.4 Spider taxa richness collected from each drainage ditch across each sampling day via ground litter sampling.

To compare the spider taxa collected across all ditches and sampling periods of spider taxa were classified into four levels of presence in drainage ditches: dominant, common, uncommon and rare. “Dominant” taxa are classified as present in 7 or more of the drainage ditches sampled during any the 3 sampling periods. Spider taxa that meet this requirement are *Oxyopes* (Oxyopidae) and *Maevia* (Salticidae). “Common” spider taxa are classified as present between 4 to 6 drainage ditches during any of the sampling periods. Spider taxa that meet this requirement were *Pachygnatha* (Tetragnathidae) and *Tetragnatha* (Tetragnathidae). “Uncommon” spider taxa are classified as present in 2 to 3 drainage ditches during any of the sampling periods. Spider taxa that meet this requirement were *Erigone* (Linyphiidae), *Parasteatoda* (Theriididae), *Bassaniana* (Thomisidae) *Missumessus* (Thomisidae), and *Xysticus* (Thomisidae). All spider taxa present in only 1 drainage ditch during any sampling period were considered “Rare” taxa for that sampling period (Tables 1.3, 1.4. and 1.5).

Table 1.3 Spider taxa presence-absence matrix of spiders collected from sweeps and litter samples during the June sampling period.

Spider Taxa		COOP			HOW			MAS			UMES			WYE		
Family	**Genus**	**East**	**South**	**West**	**North**	**Phrag**	**South**	**Field**	**North**	**South**	**Cornpepper**	**Palmetto**	**VTPoll**	**East**	**West**	**Field Plot**
Anyphaenidae	*Hibana*	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-
Araneidae	*Araniella*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Neoscona	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-
	Larinioides	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-
	Ocrepeira	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-
Antrodiaetidae	*Antrodiaetus*	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-
Atypidae	*Sphodros*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linyphiidae	*Erigone*	-	-	S	-	-	-	-	S	-	-	S	-	-	-	-
	Juvenile Linyphiid	-	L	S	-	-	-	-	-	-	-	S	-	-	-	-
Lycosidae	*Trochosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Juvenile Lycosid	-	-	-	-	L	-	-	L	-	L	-	-	-	-	-
Oxyopidae	*Oxyopes*	-	-	-	S	-	-	S	-	-	S	-	S	-	S	S
Philodromidae	*Philodromous*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tibellus	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-
Pisauridae	*Dolomedes*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pisaurina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pholcidae	*Pholcus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salticidae	*Habronattus*	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-
	Maevia	-	-	-	S	-	S	S	S	-	-	S	-	-	S	S
	Peckhamia	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-
	Sassacus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Juvenile Salticid	-	S	-	-	-	-	S	-	-	S	S	S	S	-	S
Tetragnathidae	*Pachygnatha*	-	-	-	S	S	S	-	-	S	-	-	-	-	S	S
	Tetragnatha	-	-	S	-	-	-	-	S	-	S	-	-	-	-	S
Theridiidae	*Parasteatoda*	-	S	-	-	-	-	-	-	-	-	-	-	S	-	S
	Styopis	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-
	Juvenile Theridid	-	-	-	L	-	-	-	-	-	L	S	-	-	-	S
Theridosomatidae	*Theridosoma*	-	-	-		-	S	-	-	-	-	-	-	-	-	-
Thomisidae	*Bassaniana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mechaphesa	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-
	Misumessus	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-
	Ozyptilla	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Xysticus	-	S	-	-	-	-	-	-	-	S	-	-	-	-	-
	Juvenile Thomisid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1.4 Spider taxa presence-absence matrix of spiders collected from sweeps and litter samples during the July sampling period.

Spider Taxa		COOP			HOW			MAS			UMES			WYE		
Family	**Genus**	**East**	**South**	**West**	**North**	**Phrag**	**South**	**Field**	**North**	**South**	**Cornpepper**	**Palmetto**	**VTPoll**	**East**	**West**	**Field Plot**
Anyphaenidae	*Hibana*	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
Araneidae	*Araniella*	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-
	Neoscona	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Larinioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ocrepeira	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antrodiaetidae	*Antrodiaetus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atypidae	*Sphodros*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linyhpiidae	*Erigone*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Juvenile Linyhpiid	S	S/L	-	S	-	-	-	S	L	L	S	-	-	L	L
Lycosidae	*Trochosa*	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-
	Juvenile Lycosid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L
Oxyopidae	*Oxyopes*	S	-	S	-	-	-	-	-	-	S	S	S	S	-	S
Philodromidae	*Philodromous*	-	S	-	-	-	-	-	-	-	-	-	S	-	-	-
	Tibellus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pisauridae	*Dolomedes*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pisaurina	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-
Pholcidae	*Pholcus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salticidae	*Habronattus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Maevia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peckhamia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sassacus	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-
	Juvenile Salticid	-	-	S	S	L	L	S	-	-	-	S	-	S	-	-
Tetragnathidae	*Pachygnatha*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tetragnatha	S	-	S	S	-	-	-	-	-	S	-	-	-	-	-
Theridiidae	*Parasteatoda*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Styopis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Theridosomatidae	*Theridosoma*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thomisidae	*Bassaniana*	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Mechaphesa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Misumessus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ozyptilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Xysticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Juvenile Thomisid	-	L	-	-	S/L	S/L	-	-	L	L	-	-	-	-	S

Table 1.5 Spider taxa presence-absence matrix of spiders collected from sweep/litter samples during the August sampling period.

Spider Taxa		COOP			HOW			MAS			UMES			WYE		
Family	**Genus**	**East**	**South**	**West**	**North**	**Phrag**	**South**	**Field**	**North**	**South**	**Cornpepper**	**Palmetto**	**VTPoll**	**East**	**West**	**Field Plot**
Anyphaenidae	*Hibana*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Araneidae	*Araniella*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Neoscona	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Larinioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ocrepeira	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antrodiaetidae	*Antrodiaetus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atypidae	*Sphodros*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linyhpiidae	*Erigone*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lycosidae	*Trochosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyopidae	*Oxyopes*	-	-	-	S	S	-	-	-	S	-	S	-	S	-	S
Philodromidae	*Philodromous*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tibellus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pisauridae	*Dolomedes*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L
	Pisaurina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pholcidae	*Pholcus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salticidae	*Habronattus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Maevia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Peckhamia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sassacus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tetragnathidae	*Pachygnatha*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Tetragnatha	-	-	-	-	-	-	-	-	-	S	-	S	-	S	-
Theridiidae	*Parasteatoda*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Styopis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Theridosomatidae	*Theridosoma*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thomisidae	*Bassaniana*	-	-	-	-	-	-	-	-	-	S	-	-	-	L	S
	Mechaphesa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Misumessus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ozyptilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Xysticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Spider functional feeding group composition differed from ditch to ditch and changed within each ditch as the summer progressed (Tables 1.6, 1.7, and 1.8). Generally, spiders belonging to the “stalker” feeding group, such as salticids and oxyopids, became more prevalent in ditches as the summer progressed, as they began to take up a larger proportion of the feeding group assemblages during the July and August sampling periods. Spiders belonging to the “wandering sheet weaver” feeding group, such as linyphiids, became less prevalent in ditches as the summer progressed, as they comprised a lesser proportion of the feeding group assemblages during the July and August sampling periods than the June sampling period. Generally, functional feeding assemblages in drainage ditches simplified over the course of the summer, with “stalkers”, “ground runners”, “ambushers” and “orb weavers” becoming more dominant over time.

Table 1.6 Functional feeding group composition of spider assemblages in all drainage ditches during the June sampling period.

Farm	Ditch	% Ambushers	% Foliage Runner	% Ground Runner	% Orb Weaver	% Space Web Builder	% Stalkers	% Burrowing	% Wandering Sheet Weaver
COOP	East	100	-	-	-	-	-	-	-
	South	25	0	-	-	37	13	-	13
	West	-	-	-	11	-	-	-	89
HOW	North	7	-	-	46	7	40	-	-
	Phrag	-	-	16	67	-	-	-	17
	South	-	-	-	36	-	64	-	-
MAS	Field	-	-	-	33	-	67	-	-
	North	4	-	4	48	-	-	-	44
	South	-	-	-	100	-	-	-	-
UMES	Cornpepper	12	-	12	13	13	50	-	-
	Palmetto	5	-	-	-	6	11	-	78
	VTPoll	20	-	-	-	-	80	-	-
WYE	East	-	-	-	75	-	25	-	-
	FieldPlot	-	-	-	28	29	43	-	-
	West	-	-	-	50	-	50	-	-

Table 1.7 Functional feeding group composition of spider assemblages in all drainage ditches during the July sampling period.

Farm	Ditch	% Ambushers	% Foliage Runner	% Ground Runne	% Orb Weaver	% Space Web Builder	% Stalkers	% Burrowing	% Wandering Sheet Weaver
COOP	**East**	17	-	-	17	-	33	-	33
	South	40	-	-	-	-	20	-	40
	West	34	-	11	11	-	33	-	11
HOW	**North**	7	-	-	46	0	40	-	-
	Phrag	60	-	-	20	-	20	-	-
	South	43	-	-	14	-	43	-	-
MAS	**Field**	-	-	-	-	-	100	-	-
	North	-	-	-	-	-	-	-	-
	South	-	-	-	-	-	-	-	-
UMES	**Cornpepper**	11	11	-	-	-	67	-	11
	Palmetto	50	-	-	20	-	60	-	20
	VTPoll	50	-	-	-	-	50	-	-
WYE	**East**	-	-	-	-	-	100	-	-
	FieldPlot	16	-	17	-	-	50	-	17
	West	-	-	-	-	-	67	-	33

Table 1.8 Functional feeding group composition of spider assemblages in all drainage ditches during the August sampling period.

Farm	Ditch	% Ambushers	% Foliage Runner	% Ground Runne	% Orb Weaver	% Space Web Builder	% Stalkers	% Burrowing	% Wandering Sheet Weaver
COOP	**East**	-	-	-	-	0	67	-	22
	South	-	-	33	-	-	67	-	-
	West	20	-	-	-	-	80	-	-
HOW	**North**	-	-	37	-	-	63	-	-
	Phrag	-	-	25	-	-	50	-	25
	South	45	-	-	-	-	55	-	-
MAS	**Field**	100	-	-	-	-	-	-	-
	North	-	-	-	-	-	-	-	-
	South	-	-	-	-	-	100	-	-
UMES	**Cornpepper**	33	-	33	33	-	-	-	-
	Palmetto	-	-	40	20	-	40	-	-
	VTPoll	-	-	34	33	-	33	-	-
WYE	**East**	-	-	67	-	-	33	-	-
	FieldPlot	25	-	25	-	-	50	-	-
	West	16	-	33	17	-	17	-	17

To discern which ditch spider assemblages were more similar to one another, the Bray-Curtis dissimilarity cluster analysis was used to create a matrix of the abundance of spiders collected per genus from each ditch across all sampling periods. The result was a hierarchical cluster dendrogram with no clustering issues (Figure 1.5). The Bray-Curtis dissimilarity cluster analysis that was created from a matrix using the abundance of spiders collected per functional feeding group from each ditch across all sampling periods encountered a clustering issue with four drainage ditches that were unable to be accurately placed in the dendrogram. (Figure 1.6). Overall, the variability of spider assemblages of drainage ditches within farms was similar to the variability of these ditches across farms. Spider assemblages in drainage ditches were not found to cluster by any physical ditch characteristic, plant taxa richness, or plant Shannon diversity.

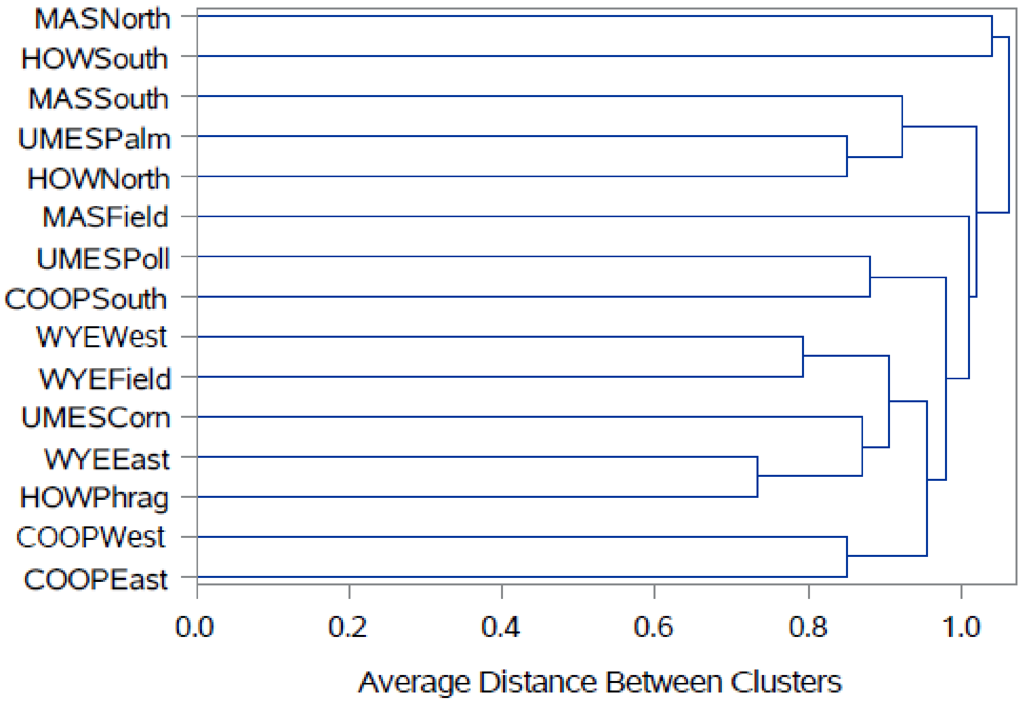

Figure 1.5 Cluster analysis dendrogram of the Bray-Curtis dissimilarity matrix created using spider genera within in each drainage ditch combining all sampling dates. Nodes are named with a farm prefix (MAS, HOW, WYE, COOP, UMES) followed by unique ditch identifiers. The only explanatory variable the clusters appeared to form by was by the farm the drainage ditches were located.

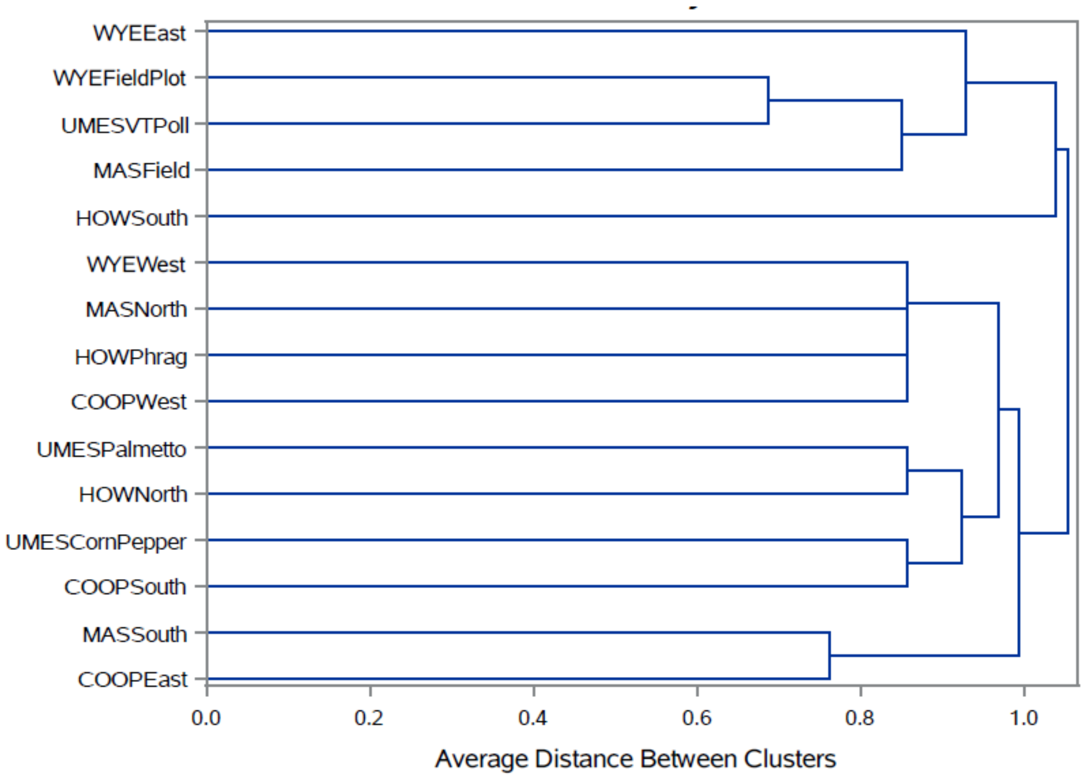

Figure 1.6 Cluster analysis dendrogram of the Bray-Curtis dissimilarity matrix created using the abundance of spiders of all FFGs within in each drainage ditch combining all sampling dates. Nodes are named with a farm prefix (MAS, HOW, WYE, COOP, UMES) followed by one of three unique ditch identifiers from each farm. A polytomy occurs between 4 drainage ditches due to equal spider abundances.

Plant diversity and environmental conditions

A total of 44 plant families were identified across all 15 drainage ditches and sampling dates during our sampling effort in 2017, encompassing 96 genera (Table 1.9). The 3 most commonly identified families in our 2017 sampling effort were Poaceae, Anacardiaceae, and Asteraceae. The number of plant genera identified per drainage ditch during any given sampling period ranged from 7-15 plant genera. *Solidago* (Family Asteraceae), *Festuca* (Family Poaceae) and *Toxicodendron* (Family Anacaridaceae) were the most commonly identified plant genera in drainage ditches, which were observed 138, 113 and 105 times respectively during our plant collection samples. The mean percent coverage provided by these 3 genera in the drainage ditches they were observed at ranged from 17% *(Toxicodendron*) to 35% *(Festuca*). Other plant genera, such as *Dichanthelium* (Family Poaceae), on average provided more coverage in the ditches they were observed at but were less common in our collection (Table 1.10).

Table 1.9 Plant families and genera identified from all drainage ditches and sampling dates during the summer 2017 sampling effort.

Family	Genus
Adoxaceae	Unidentified
Alismataceae	*Sagittaria*
Aliaceae	*Allium*
Altingiaceae	*Liquidambar*
Amaranthaceae	*Amaranthus*
Amaryllidaceae	Unidentified
Anacardiaceae	*Toxicodendron*
	Unidentified
Apiaceae	*Daucus*
Apocynaceae	*Asclepias*
Araceae	Unidentified
Aroideae	Unidentified
Asclepiadaceae	*Apocynum*
Asteraceae	*Achillea*
	Ambrosia
	Artemisa
	Bidens
	Chrysopsis
	Cirisium
	Conyza
	Erigeron
	Eupatorium
	Helianthus
	Lactuca
	Mikania
	Solidago
	Taraxacum
	Xanthium
	Unidentified
Bignoniaceae	*Campsis*
	Unidentified
Blechnaceae	*Woodwardia*
Boraginaceae	*Nemophila*
Brassicaeae	*Barbarea*
Caprifoliaceae	*Lonicera*
Caryophyllaceae	*Dianthus*
Commelinaceae	*Commelina*
	Unidentified
Compositae	*Mikania*
Convolvulaeae	*Ipomoea*
	Unidentified
Cyperaceae	*Carex*
Euphorbiaceae	*Euphorbia*
Fabaceae	*Chamaecrista*
	Glycine
	Lespedeza
	Medicago
	Trifolium
	Vicia
	Quercus
	Unidentified
Geraniaceae	Unidentified
Hydrangeaceae	*Hydrangea*
Juglandaceae	Unidentified
Juncaceae	Unidentified
Lamiaceae	*Agastache*
	Coleus
	Glechoma
Moraceae	*Morus*
Oxalidaceae	*Oxalis*
Plantaginaceae	*Plantago*
Poaceae	*Bromus*
	Dichanthelium
	Digitaria
	Festuca
	Hordeum
	Lolium
	Microstegium
	Pancium
	Paspalum
	Phalaris
	Phragmites
	Poa
	Setaria
	Unidentified
Polygonaceae	*Polygonum*
	Rumex
	Unidentified
Rosaceae	*Fragaria*
	Prunus
	Rosa
	Rubus
	Unidentified
Saliaceae	Unidentified
Sapindaceae	*Acer*
Scrophulariaceae	*Mimulus*
	Verbascum
	Unidentified
Solanaceae	*Solanum*
	Unidentified
Typhacea	*Typha*
Urticaeae	*Urtica*
Violaceae	*Viola*
Vitaceae	*Parthenocissus*
	Vitis
	Unidentified

Table 1.10 The 10 most commonly identified plant genera and their mean coverage in drainage ditches across all ditches and sampling dates collected during the summer 2017 sampling effort.

Family	**Genus**	**Number of Observations**	**Mean % Coverage**
Asteraceae	*Solidago*	138	19.50 ± 17.10
Poaceae	*Festuca*	113	35.60 ± 26.40
Anacardiaceae	*Toxicodendron*	105	17.40 ± 19.60
Rosaceae	*Rubus*	95	17.70 ± 14.50
Poaceae	*Phragmites*	77	33.50 ± 31.20
Caprifoliaceae	*Lonicera*	72	15.80 ± 17.00
Apocynaceae	*Apocynum*	54	14.80 ± 14.60
Convolvulaceae	*Ipomoea*	47	10.20 ± 14.70
Vitaceae	*Parthenocissus*	46	14.00 ± 11.30
Oxalidaceae	*Oxalis*	41	8.50 ± 8.90
Poaceae	*Dichanthelium*	31	32.10 ± 28.00

When ranked by relative abundance in each drainage ditch, the plant assemblages in each drainage ditch presented different patterns of diversity and evenness. During the June sampling period, the UMES Cornpepper and WYE East drainage ditches presented the least diverse plant assemblages, with only 5 plant taxa identified in those ditches. On the other hand, the COOP East and HOW South drainage ditches presented the most diverse plant assemblages during the June sampling season, each possessing 13 plant taxa. During the July sampling season, the WYE East ditch was again presented the least diverse plant assemblage with 6 plant taxa identified. Conversely, the MAS Field and MAS North drainage ditches presented the most diverse plant assemblages during the July sampling period, each possessing 11 plant taxa. However, during the August sampling season, the HOW Phrag drainage ditch presented the least diverse plant assemblage, with only 3 plant taxa identified that sampling season. The drainage ditch with the most diverse plant assemblage during the August sampling period was the MAS South drainage ditch, with 13 plant taxa identified. The evenness of the plant assemblages in drainage ditches varied greatly from ditch to ditch and across sampling periods, with some ditches presenting very even plant assemblages, with few or no dominant taxa, to ditches completely dominated by one plant genus (Tables 1.11-1.13).

Table 1.11 Ranked relative plant abundances for each drainage assessed during the June sampling period.

Location		Abundance Rank												
Farm	**Ditch**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
COOP	**East**	26.9%	17.8%	17.1%	9.1%	9.1%	8.7%	5.1%	2.2%	0.4%	0.4%	0.4%	0.4%	0.4%
	South	37.8%	23.9%	11.2%	7.7%	6.6%	6.2%	2.3%	2.3%	0.8%	0.8%	0.8%	-	-
	West	27.1%	23.5%	14.6%	10.5%	8.5%	6.9%	5.3%	2.8%	0.4%	0.4%	-	-	-
HOW	**North**	58.0%	21.0%	6.0%	3.0%	1.0%	1.0%	0.6%	0.3%	0.1%	-	-	-	-
	Phrag	76.0%	8.0%	5.0%	4.0%	2.0%	1.0%	0.2%	-	-	-	-	-	-
	South	47.0%	14.0%	13.0%	5.0%	5.0%	4.0%	3.0%	1.0%	0.9%	0.6%	0.3%	0.3%	0.3%
MAS	**Field**	26.6%	22.7%	17.4%	10.6%	7.7%	6.3%	2.9%	0.5%	0.5%	0.5%	0.5%	-	-
	North	53.9%	21.8%	12.5%	6.5%	2.5%	1.9%	0.6%	0.3%	-	-	-	-	-
	South	50.0%	16.4%	12.7%	6.5%	2.2%	2.2%	0.6%	0.5%	0.3%	0.3%	-	-	-
UMES	**Cornpepper**	52.2%	33.3%	10.0%	3.3%	1.1%	-	-	-	-	-	-	-	-
	Palmetto	36.6%	17.9%	15.6%	12.5%	8.0%	4.0%	2.7%	0.9%	0.9%	0.4%	0.4%	-	-
	VTPoll	59.7%	19.5%	8.8%	6.6%	2.7%	0.9%	0.9%	0.9%	-	-	-	-	-
WYE	**East**	92.6%	2.2%	1.9%	1.9%	1.9%	-	-	-	-	-	-	-	-
	FieldPlot	42.7%	30.9%	10.2%	4.9%	4.5%	2.8%	2.4%	0.8%	0.4%	0.4%	-	-	-
	West	50.2%	41.5%	6.7%	1.6%	0.3%	-	-	-	-	-	-	-	-

Table 1.12 Ranked relative plant abundances for each drainage assessed during the July sampling period.

Location		Abundance Rank										
Farm	**Ditch**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
COOP	**East**	51.8%	22.0%	14.8%	3.6%	3.6%	2.2%	1.7%	0.3%	-	-	-
	South	37.0%	20.5%	16.7%	12.2%	7.1%	4.8%	1.5%	0.3%	-	-	-
	West	38.7%	24.8%	9.6%	8.9%	5.7%	5.3%	3.5%	2.5%	0.7%	0.4%	-
HOW	**North**	58.0%	11.0%	7.0%	5.0%	2.0%	1.0%	1.0%	0.8%	0.2%	0.2%	-
	Phrag	68.0%	10.0%	10.0%	4.0%	4.0%	1.0%	0.1%	-	-	-	-
	South	29.0%	18.0%	12.0%	10.0%	9.0%	7.0%	5.0%	3.0%	1.0%	1.0%	-
MAS	**Field**	28.2%	19.2%	17.3%	15.0%	12.0%	3.8%	2.3%	0.8%	0.8%	0.4%	0.4%
	North	37.0%	24.0%	10.0%	10.0%	5.0%	5.0%	3.0%	1.0%	0.3%	0.2%	0.1%
	South	26.1%	21.7%	17.2%	9.2%	7.5%	6.4%	5.0%		-	-	-
UMES	**Cornpepper**	48.9%	17.3%	15.1%	10.2%	3.1%	2.7%	0.9%	0.9%	0.4%	0.4%	-
	Palmetto	32.4%	23.0%	10.3%	10.3%	9.8%	9.8%	0.5%	0.5%	0.5%	-	-
	VTPoll	25.0%	14.0%	6.8%	2.4%	2.1%	1.0%	0.3%	0.3%	-	-	-
WYE	**East**	81.2%	6.4%	4.6%	4.6%	1.8%	1.8%	-	-	-	-	-
	FieldPlot	38.5%	32.6%	12.8%	4.8%	4.4%	3.7%	2.6%	0.4%	0.4%	-	-
	West	34.6%	22.6%	4.5%	3.9%	2.4%	0.3%	0.3%	0.3%	-	-	-

Table 1.13 Ranked relative plant abundances for each drainage assessed during the August sampling period.

Location		Abundance Rank												
Farm	**Ditch**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
COOP	**East**	36.4%	22.5%	16.3%	10.9%	2.7%	2.3%	2.3%	0.4%	0.4%	0.4%	0.4%	-	-
	South	34.6%	27.4%	11.4%	11.4%	9.3%	5.1%	0.8%	-	-	-	-	-	-
	West	83.8%	7.7%	2.7%	2.7%	1.5%	0.8%	0.4%	-	-	-	-	-	-
HOW	**North**	52.0%	22.0%	4.0%	4.0%	2.0%	2.0%	1.0%	1.0%	0.8%	0.3%	0.2%	0.1%	-
	Phrag	44.0%	24.0%	20.0%	-	-	-	-	-	-	-	-	-	-
	South	26.0%	13.0%	10.0%	9.0%	8.0%	7.0%	2.0%	2.0%	-	-	-	-	-
MAS	**Field**	32.0%	25.0%	15.0%	9.0%	4.0%	3.0%	3.0%	1.0%	1.0%	0.6%	0.6%	-	-
	North	39.5%	12.1%	9.0%	9.0%	7.6%	6.7%	5.8%	4.0%	2.7%	2.7%	0.9%	0.4%	-
	South	22.8%	19.1%	13.6%	11.7%	8.6%	4.3%	4.3%	1.2%	1.2%	0.6%	0.6%	0.6%	0.6%
UMES	**Cornpepper**	61.3%	17.2%	17.2%	2.9%	0.5%	0.5%	-	-	-	-	-	-	-
	Palmetto	21.0%	21.0%	17.6%	17.6%	9.9%	8.8%	4.8%	4.4%	1.1%	-	-	-	-
	VTPoll	28.1%	21.8%	18.2%	16.8%	8.8%	4.9%	0.4%	0.4%	0.4%	0.4%	-	-	-
WYE	**East**	86.6%	5.4%	2.7%	2.3%	2.3%	0.8%	-	-	-	-	-	-	-
	FieldPlot	33.3%	22.2%	22.2%	11.1%	5.6%	5.6%	-	-	-	-	-	-	-
	West	90.4%	2.0%	2.0%	2.0%	2.0%	0.7%	0.7%	0.7%	0.7%	-	-	-	-

Discussion

I sought to characterize the diversity and abundance of spider assemblages in drainage ditches, assess how spider assemblages in drainage ditches differ between ditches and change as the summer progresses and assess how plant assemblages and the physical characteristics of drainage ditches influence the spider assemblages living within them. I learned that drainage ditches possess diverse spider assemblage, which include 14 families encompassing 25 genera. Additionally, I learned that spider abundance and taxa richness in drainage ditches differ between individual ditches and well as change as the summer progresses.

In terms of the potential of spiders in drainage ditches as natural enemies, spider taxa belonging to the "dominant" and "common" presence levels are likely the greatest contributors to pest predation by spiders from ditches out of the entire ditch spider assemblage, simply due to their abundance in ditch ecosystems. Of these "dominant" and "common" spiders, only one spider taxa (*Oxyopes)* has previous evidence of their efficacy as natural enemies in agroecosystems and could impact pest populations in neighboring croplands (Young & Lockley 1985, Nyffeler et a. 1987). The other three spider taxa in the "dominant and "common" presence levels (*Maevia, Pachygnatha, Tetragnatha*) have previous evidence or being ubiquitous, voracious predators or being known to take advantage of riparian areas as a food source (Gillespie 1987, Jackson and Pollard 1996). Other spiders in the "uncommon", specifically the thomisid taxa collected (*Bassaniana, Missumessus, Xysticus*) also have previous evidence of efficacy as natural enemies, and likely contribute in small ways to pest predation by spiders from drainage ditches (Riechert & Lockley 1984, Breene et al. 1990).

Spider abundance collected in sweep samples varied greatly across drainage ditches and sampling months. The highest sweep spider abundance was collected during the June sampling period, followed by July and August sampling periods. This trend was not repeated in the litter samples, with the highest litter spider abundance being collected in August followed by the July and June sampling periods. The increase of litter spider abundance and decrease of sweep spider abundance as the summer progresses may be explained by multiple factors. Spiders belonging to our most commonly collected spider, *Oxyopes* (Oxyopidae), are known to reproduce in early June and promptly leave their reproductive habitat after egg sac eclosion (Nyffeler et al. 1987). In my collections, adult *Oxyopes* were most abundant in our June sweep samples but became less abundant as the summer progressed. Along with that trend, juvenile *Oxyopes* collected from litter samples increased as the summer progressed. As a result of these trends, I believe spider phenology may influence what spider taxa and spider life stages are present in drainage ditches as the summer progresses. Aside from changes to ditch spider communities due to spider phenology, spider communities in drainage ditches may also change due to spider dispersal. Due to the rough, disturbed nature of agricultural fields, spiders are known to inhabit less disturbed microhabitats near croplands during times when croplands are less suitable for habitation, such as early in the crops growth cycle or after cultivation events (Samu et al. 1999). Additionally, many adult ground dwelling spiders that could be targeted by litter sampling, such as lycosids or linyphiids, are agile enough to escape this type of sampling (Green 1999). Spiderling lycosids and linyphiids are less agile than adult specimens, which can cause the spiderlings to be collected more frequently as they are less capable of escaping litter sampling.

The composition of the spider functional feeding groups of each drainage ditch informs what predatory niches are being filled by spiders in drainage ditches (Nyffeler et al. 1994). Over the course of our summer 2017 sampling, the spider functional feeding groups in drainage ditches change as the summer progresses. Generally, spiders belonging to the "ground runner" and "ambusher" feeding groups begin to occupy a higher proportion of the functional feeding assemblages in ditches as the summer progresses. Additionally, other functional feeding groups such as the "sheet-weavers" and "ambushers" occupy a lesser proportion of the functional feeding assemblages in ditches as the summer progresses. These changes in the functional feeding assemblages in drainage ditches likely represent changes in the ditch habitat that caters to certain feeding niches for spider. As habitat niches open up as the summer progresses, spiders that are specialized in utilizing said habitats will move in and take advantage of new resources (Scheidler 1990).

In addition to the findings presented regarding spider abundance, taxa richness and functional feeding groups, Bray-Curtis dissimilarity analyses also provide evidence that spider phenology and habitat availability are likely drivers of spider assemblage structure in ditches. The Bray-Curtis dissimilarity analysis comparing ditch spider communities observed only light clustering of ditches located at the same farm, but not between ditches of similar plant communities or ditch characteristics. However, even with changing the resolution of the analysis by grouping spiders by their functional feeding guild, Bray-Curtis dissimilarity cluster analysis did not group drainage ditches together by any of the variables I assessed in my sampling approach. This likely indicates that spider community structure is either driven by the regional spider metacommunity, or other environmental influencer like prey abundance. (Baba and Tanka 2016). As habitat availability is a combination of different environmental factors, such as prey availability and foliage structure, it is likely that it and the local spider metacommunity are responsible for the spider communities in drainage ditches, especially when applying metacommunity theory such as patch dynamics to the system (Winemiller et al. 2010). This explanation is further supported by the lack of relevant significant findings relating the ditch spider community metrics to plant and physical ditch characteristics.

My assessment of the spider communities in drainage ditches was a small component of a larger study focusing on the biodiversity of drainage ditches, and for this reason my depiction of the spider communities in drainage ditches is underestimates certain spider taxa. This underestimation is due to the lack of pitfall sampling in our drainage ditch assay, as ground spiders are better represented in data sets that utilize this sampling method (Merrett and Snazell 1983). Due to the nature of the larger biodiversity assessment and long traveling distance needed to sample these drainage ditches, we did not perform pitfall trapping to allow us to rapidly assess as many drainage ditch ecosystems as possible.

Overall, drainage ditches present diverse and abundant spider assemblages which warrant further investigation into drainage ditches as sources of spiders in agroecosystems. The most common spider genera inhabiting drainage ditches potentially have value as natural enemies in agroecosystems, while the plant community present in drainage ditches likely supplies the habitat structures necessary to house these spiders. Further conservation of potential sources of natural enemies is likely to increase pest suppression by these natural enemies in nearby agroecosystems, so further investigation into the intensity of natural enemy predation provided to nearby croplands by organisms living in drainage ditches is necessary. This exploration of spider movement to croplands from drainage ditches is the primary focus of the next chapter of my thesis.

Chapter 2: Dynamics of spider assemblages in drainage ditches and adjacent organic soybeans

Abstract

Agricultural drainage ditches, which are typically used to provide hydrological control for croplands, have recently begun to receive attention as potential sources of natural enemies for adjacent croplands. Of the natural enemies found in drainage ditches, spiders have recently been supported as potential candidates to enhance conservation biocontrol in these adjacent croplands. To better understand how spiders in drainage ditches may impact adjacent croplands my research objectives were: (1) to assess how spider assemblages in drainage ditches and their neighboring croplands change during the soybean growing season, (2) to determine what spiders colonize croplands from drainage ditches, and (3) to identify what environmental conditions influence spider assemblages and colonization between drainage ditches and croplands. I collected spiders from habitats that were located at specific distances into an organic soybean fields starting from its associated drainage ditch. During summer 2018, one drainage ditch and its adjacent soybean were sampled in this fashion via sweep netting and pitfall trapping. During the next soybean growing season in 2019, my methodology was expanded upon to include 3 drainage ditches and assess environmental data such as prey abundance, ground-level temperature and humidity, and plant assemblage metrics. I found that drainage ditches possess spider taxa that migrate to soybean fields as the growing season

progresses, as soybean fields begin to offer comparable prey availability as drainage ditches later in the growing season. Prey abundance was found possess a positive significant relationship with spider abundance in drainage ditches and adjacent soybean fields. Plant diversity in ditches became smaller as the growing season progressed, which was related to reduced prey abundance for spiders. In contrast, soybean fields increased in prey abundance as they grew. Overall, spider diversity and abundance in drainage ditches shifted to adjacent soybean fields as the soybean growing season progressed.

Introduction

In organic agriculture, natural enemies are a major component of arthropod pest management in the absence of commercial anthropogenic inputs (Marc et al. 1999, Symondson et al. 2002, Sandhu et al. 2010). Of the natural enemies inhabiting organic croplands, generalist predators have long been considered for their pest management applications (Nyffeler and Benz 1987, MacLeod et al. 2004). Among the generalist predators found in organic agroecosystems, spiders are the most abundant generalists found in croplands, with their populations sometimes tenfold higher than other generalists such as carabids or reduviids (Halaj et al. 2000, Rand 2017). The potential impact of spiders as natural enemies of agricultural pests is the result of the spider assemblage as a whole rather than individual spider taxa, as each spider lends its own feeding strategy to the overall pest suppression performed by spiders (Nyffeler and Benz 1987). Previous evidence suggests that more diverse spider communities deliver better pest suppression in organic croplands, which has been attributed to the diversity of feeding strategies associated with spider diversity, as more diverse feeding strategies lead to more opportunities for pests to be eaten by spiders (Riechert and Bishop 1990). Additionally, higher spider populations in general have also been associated with reduced herbivore damage in field crops such as soybeans (Carter and Rypstra 1995).

Spider assemblages in croplands have received little attention regarding their sources in the farmscape (Nyffeler and Benz 1987). Previously, the long-held assumption of how spiders colonize field crops was that spiders inhabiting croplands were simply the offspring of the spider survivors from the last harvest or cultivation event (Xiu et al. 2018). However, other research suggests that spiders may colonize croplands from neighboring uncropped areas in farmscapes (Halaj et al. 2000). These uncropped areas of farmscapes, such as hedgerows and grass prairies, have been found to contain spider assemblages that significantly differ from those in field crops, with uncropped areas possessing higher spider diversity and abundance (Oberg et al. 2007). Agricultural drainage ditches, an uncropped area associated with crop fields that are created to provide hydrological control for these fields, have become the subject of study for their value as potential habitats for natural enemies (Herzon and Helenius 2008). Drainage ditches possess characteristics that likely support a larger spider diversity than spider assemblages living in croplands, such as more diverse physical habitat structure and higher prey availability especially during early crop growth stages or disturbances in croplands (Baba and Tanaka 2016). Drainage ditches are also less disturbed than the croplands they border, as drainage ditches typically are mowed only at the end of each summer to prevent woody plants from growing too large, while numerous cultivation events can occur throughout a crop’s growth (Schmidt et al. 2005).

Spiders have previously demonstrated the ability to select habitats with higher prey availability and more diverse physical habitat structures and will move to habitats with better survival conditions (Riechert 1985, Mcnett and Rypstra 2000). Each individual spider species lives in specifically defined habitat niches that are limited by conditions such as physical habitat structure, temperature, humidity, prey availability and resource competition (Duffey 1966). As habitat conditions change in agroecosystems, such as the growth of summer crops, spiders living in nearby uncropped habitats can colonize crop habitats, which often possess less competition for habitat structure and new prey resources (Luczak 1966). Since spiders possess this habitat selecting behavior, it is possible that spiders inhabiting drainage ditches may move to colonize nearby croplands as the crop’s growing cycle progresses and consume economic pests in those crops (Marc et al. 1983). Additionally, spiders inhabiting croplands may move to nearby drainage ditches during times when the cropland habitat is disturbed, such as during harvest or cultivation events (Halaj et al. 2000).

This study was inspired by recent efforts to identify the ecosystem services that agricultural drainage ditches provide to nearby croplands. In the first chapter of my thesis, I described the diversity and abundance of spider assemblages broadly inhabiting drainage ditches in Maryland. In this second chapter of my thesis, I performed field experiments to determine what extent the composition of spider assemblages in drainage ditches influence other assemblages in nearby croplands, along with how these assemblages change throughout the growth cycle of organic soybeans. Specifically, my research objectives for this chapter of my thesis were (1) to assess how spider assemblages in drainage ditches and their neighboring croplands change throughout the soybean growing season, (2) to determine what spiders colonize croplands from drainage ditches, and (3) to identify what environmental conditions influence spider assemblages and colonization between drainage ditches and croplands.

Methods

Project overview

The experiments were performed during two sampling seasons; the summers of 2018 and 2019. During the summer of 2018, I performed a preliminary experiment to test a new sampling approach for collecting spiders from drainage ditches and nearby croplands. During the summer of 2019, the sampling method was implemented in a larger-scale experiment to assess spider movement between ditches and croplands. All experiments performed during the summers of 2018 and 2019 were performed on the same organic farm that was originally codenamed COOP in the first chapter of my thesis. Soybeans were grown in all fields sampled during both sampling seasons. The soybeans planted were ‘Monocacy’ cultivar, planted 44.5 seeds/m^2 with a 12 row John Deere® 7200 planter above Falsington soil. All ditches and soybean fields sampled across both summers were all located at the COOP farm, and ditches were located inside the border of the fields. During summer 2018, one drainage ditch codenamed “East” was selected for preliminary sampling, while three drainage ditches, codenamed “South”, “Far” and “Mid” were selected for the large-scale sampling effort in 2019 (Figure 2.1). In both experiments, I defined four habitat types with different environmental and structural conditions which spiders may inhabit based on location relative to drainage ditches. The habitat types were: 1) in the drainage ditch (as far down the ditch slope without reaching water), 2) at the ditch edge where the ditch foliage and croplands met, 3) 10m into the cropland from the ditch edge (between rows of soybeans), and 4) 20m into the cropland from the ditch edge (also between rows of soybeans). Five transects, each including all four habitat types and set perpendicular to the drainage ditch, were created to act as replicates for each habitat type (Figure 2.2).

Figure 2.1 The drainage ditches sampled at the COOP farm, including their codenames and growing season sampled during the project. Image courtesy of Google Earth.

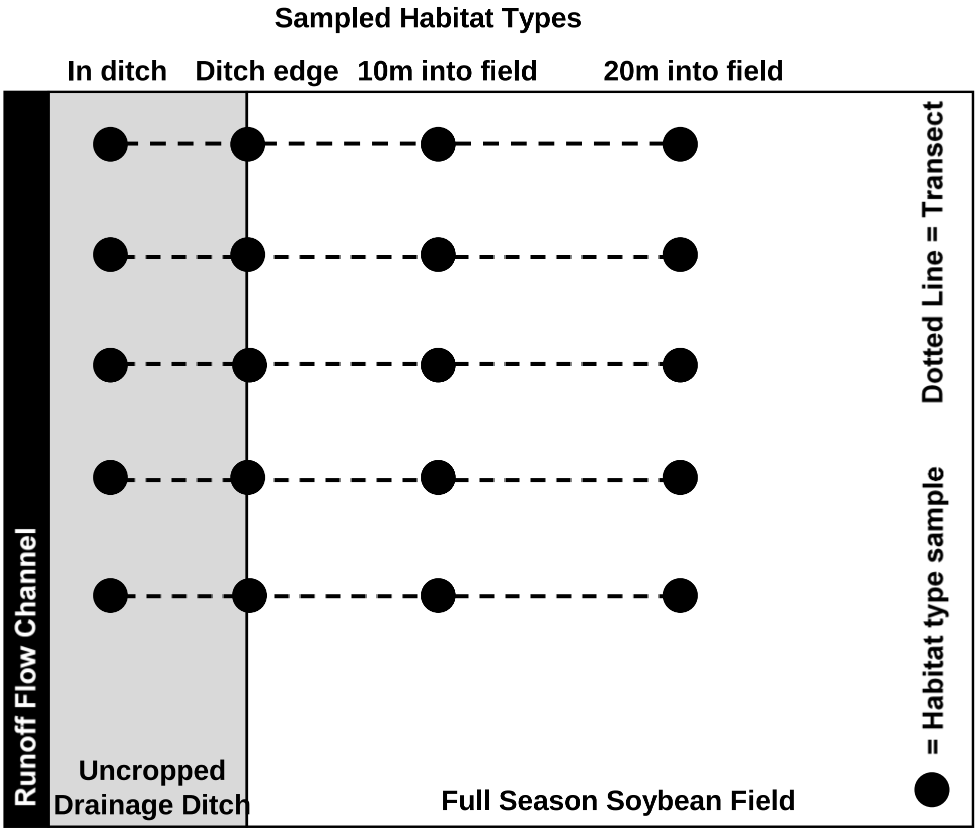

Figure 2.2 Schematic of the experimental design for pitfall trapping and foliar sweep sampling implemented in the 2018 and 2019 soybean growing seasons.

Single ditch experiment, 2018

The full season soybeans grown in the croplands neighboring the “East” drainage ditch were seeded on June 18th and harvested on November 23th. I sampled at the chosen drainage ditch and its surrounding croplands during 4 sampling periods defined by different soybean growth stages: after planting (June 28th-July 2nd), V5 (August 13th-August 17th), R4 (September 11th-September 15th) and near harvest (November 17th-21st). Notably, the soybean growing season was pushed back about a month later than normal growing seasons due to high precipitation levels throughout the late spring and early summer. At the beginning of the first sampling period at the COOP farm, I established five transects of four habitat types as previously described for a total of 20 sampling locations.

At each sampling date in 2018, one pitfall trap was installed at each of the sampling site locations. The pitfall traps were created by using a 11.5 cm diameter golf hole digger to cut a 5-inch cylindrical hole out of the ground. One 500mL plastic SOLO ®cup was fitted in the freshly dug hole, after which another plastic cup was placed inside the first cup to allow for easy sample retrieval. The top plastic cup would then be filled with approximately 100ml of propylene glycol. The soil around the lip of the top plastic cup was molded around the lip of the cup to create a flat surface to allow spider movement into the traps. The pitfall traps were then each covered with a 25cm-diameter plastic plate fastened to the earth with bolts and left to collect spiders. After 5 days, the contents of each pitfall trap were sieved through a 500µm mesh sieve, from which the contents were removed from the sieve and stored in 80% ethanol solution in 100mL snap-lock plastic jars. Samples were sorted in the lab for spiders, which were identified to lowest level taxonomy, usually species (Ubick et al. 2017, World Spider Catalog 2020).

Additionally, foliar sweep samples were collected from each habitat type replicate on each collection date for pitfall traps. Sweep samples consisted of 50 sweeps with a 38cm hoop sweep net, which were collected in 10m gaps perpendicular to each transect, between the pitfall traps that were deployed at each transect. The contents of each sample were transferred to paper bags and placed in an enclosed bucket charged with ethyl acetate to prevent spiders from escaping or preying upon each other. The sweep samples were then stored in a -20°C freezer until spiders were removed and stored in 80% ethanol. Spiders were enumerated and identified to lowest level taxonomy possible, usually species (Ubick et al. 2017, World Spider Catalog 2020).

Three ditch experiment, 2019

In the 2019 summer field season, the experimental design tested during 2018 was expanded upon to include more drainage ditches, as well as to analyze the environmental conditions present in drainage ditches and croplands. Three drainage ditches codenamed “Far”, “Mid” and “South” and their adjacent fields were sampled at similar soybean growth stages as the 2018 sampling season, but with slight modifications following guidance from the spider abundance data gathered in the first year of the project. Due to the lack of spider abundance in ditches and croplands at the sampling period at harvest time (but before the actual harvest event), I decided to instead to sample at a sampling period prior soybean planting in order to gain a better understanding of the spider assemblages in croplands prior to crop growth. I sampled ditches and their surrounding fields during four sampling periods: before planting (May 13th-May 17th), after planting (July 1st-July 5th), vegetative stage 5 (August 1st- August 5th) and reproductive stage 4 (September 11th- September 15th). However, due to the termination of a soybean field neighboring the “Far” drainage ditch after the “after planting” sampling period was sampled, another soybean field on the opposite side of the “Far” drainage ditch was sampled instead for the vegetative stage 5 and reproductive stage 4 sampling periods. This change was necessary to continue sampling in the “Far” ditch along the same timeline as the other two drainage ditches and because the terminated field was not replanted.

Pitfall and foliar sweep samples were collected as in 2018 for the three drainage ditches. Additionally, non-spider arthropods collected from both pitfall and sweep samples in 2019 were stored, counted, and identified to order to estimate the prey availability in the different habitat types. The size of all three ditches were measured at the beginning of the sampling season, including bank-to-bank width and depth using measuring tape and meter rules. Observable water flow at each ditch was also noted visually. Plant diversity and coverage was assessed using the Daubenmire cover class method (Daubemire 1959). Cover classes for plant genera in drainage ditches were recorded for five Daubenmire 20x50cm frames at each “in ditch” and “ditch edge” habitat replicate. Unknown plant specimens collected were stored plastic bags and pressed in the laboratory for later identification. Ground level temperature and humidity were assessed for the “in ditch” and “20m from ditch edge” habitat types using HOBO MX2301 Temperature/RH loggers. The ground-level loggers were each placed at one of the transects of their respective habitat types, covered with a plastic pitfall cover, and left to collect data at one-minute intervals for at least 30 minutes at each drainage ditch. Ambient temperature and relative humidity was assessed using a separate standing HOBO MX2301 logger connected to a HOBO RS1 solar radiation shield which was left to collect data at one-minute intervals for the entirety of one sampling day within a sampling period.

Statistical analyses

All statistical analyses were performed in SAS Studio (2019). Significant differences between the physical ditch characteristics of all four drainage ditches were assessed with a one-way ANOVA for each quantitative characteristic. Significant differences between the spider abundances collected at each habitat type and sampling period in 2018 were assessed with a two-way ANOVA analysis for each sampling method (pitfall trapping and sweep sampling) at $\alpha = 0.05$. Sampling period and habitat type were both treated as main effects for every two-way ANOVA analysis conducted for the 2018 spider data. Similarly, significant differences between the spider species richness identified at each habitat type and sampling period in 2018 were assessed with a two-way ANOVA analysis for each sampling method (pitfall trapping and sweep sampling) at $\alpha = 0.05$. All post hoc analysis of the main effects for the 2018 two-way ANOVAs were conducted through Tukey's HSD comparisons.

Significant differences between the spider abundances collected at each habitat type and sampling period in 2019 were assessed with a two-way ANOVA analysis for each sampling method (pitfall trapping and sweep sampling) at $\alpha = 0.05$.

Sampling period and habitat type were both treated as main effects for every two-way ANOVA analysis conducted for the 2010 spider data. Similarly, significant differences between the spider species richness identified at each habitat type and sampling period in 2019 were assessed with a two-way ANOVA analysis for each sampling method (pitfall trapping and sweep sampling) at $\alpha = 0.05$. All post hoc analysis of the main effects for the 2019 two-way ANOVAs were conducted through Tukey's HSD comparisons.

In order to compare the diversity and relative abundance of the spider assemblages present in drainage ditches and their neighboring soybean fields, the percent Bray-Curtis dissimilarity was calculated between each habitat type within each sampling period using those spider metrics. In order to identify significant associations between prey abundance and spider abundance as well as prey abundance and plant diversity, two linear regression analyses were performed at $\alpha = 0.05$. Differences between ground-level temperature and humidity between drainage ditches and in soybean fields across all sampling seasons were each analyzed with one student's t-test each.

Results

Ditch characteristics, 2018 and 2019

The physical characteristics of the drainage ditches sampled in 2018 and 2019 were similar to one another (Table 2.1). Ditch width ranged from 3.6-4.0m wide, while ditch depth ranged from 1.3-1.4m deep. Wetted width and depth in each ditch ranged from 75-110cm and 5-40cm respectively. Flow was observed at the East ditch during every sampling period conducted in 2018. Flow was only observed at the Far and Mid drainage ditches during the “After Planting” sampling period in 2019. No significant differences between any quantitative ditch characteristic were observed (ANOVA, Width: {F=0.45, df=3, p=0.72}, Depth:{F=0.21, df=3, p=0.88}, Wetted Width: {F=0.19, df=3, p=0.89}, Wetted Width {F=0.78, df=3, p=0.57}).

Table 2.1 Physical characteristics measured at each drainage ditch sampled from summers 2018 and 2019.

Farm Information				GPS location		Ditch size		Channel measures		
County	**Farm**	**Ditch**	**Year Sampled**	**North**	**East**	**Width (m)**	**Depth (m)**	**Wetted Width (cm)**	**Wetted Depth (cm)**	**ObservedFlow**
Wicomico	COOP	East	2018	N38.32633°	W75.71615°	3.6	1.3	100	40	Y
Wicomico	COOP	Far	2019	N38.22381°	W75.71856°	3.6	1.2	70	20	Y
Wicomico	COOP	Mid	2019	N38.32438°	W75.71732°	4	1.4	110	35	Y
Wicomico	COOP	South	2019	N38.32390°	W75.71815°	3.6	1.2	75	5	N

Single ditch experiment, 2018

A total of 163 spiders were collected from the East drainage ditch and its neighboring croplands by pitfall trapping across all soybean growth stages and habitat types in 2018. The "after planting" sampling period produced the highest pitfall spider abundance collected with 101 spiders, followed by the R4 sampling period with 58 spiders, the V5 sampling period with 45 spiders, and the "at harvest" sampling period with 9 spiders. Of the habitat types sampled in 2018, the ditch edge habitat type produced the highest pitfall spider abundance with 81 spiders across all sampling periods, followed by the in-ditch habitat type with 70 spiders, the "10m into field" habitat type with 32 spiders and the "20m into the field" habitat type with 31 spiders. Spider abundance within each habitat type changed as the growing season progressed (Figure 2.3). Of the juvenile spiders collected from pitfall sampling, the V5 sampling period produced the most with 5 juveniles, while the "after planting" and R4 sampling periods each produced 2 juvenile spiders. No juvenile spiders were collected during the "at harvest" sampling period by pitfall trapping. The two-way ANOVA performed to measure the variation between pitfall spider abundances at each habitat type and sampling period generated significant differences in spider abundances as a result of both main effects (habitat type and sampling period) along with the interaction of the two main effects (Two-Way ANOVA, Sampling Period Effect: {F=17.06, df=3, p<0.0001}, Habitat Type Effect:{F=3.32, df=3, p<0.05}, Interaction Effect:{F=3.45, df= 9, p<0.01}). Through Tukey's HSD comparisons of these main effect interactions, I found that the significant differences between the pitfall spider abundances of the in ditch vs. ditch edge, ditch edge vs, "10m into field”, and ditch edge vs. “20m into field” habitat types during the “after planting” sampling period were due to an interaction between the two main effects. The only other significant differences found between the pitfall spider abundances collected in 2018 were a result of the sampling period main effect, of which the “after planting” vs. V5, “after planting” vs. R4, and “after planting” vs. “at harvest” comparisons were significantly different (Table 2.2).

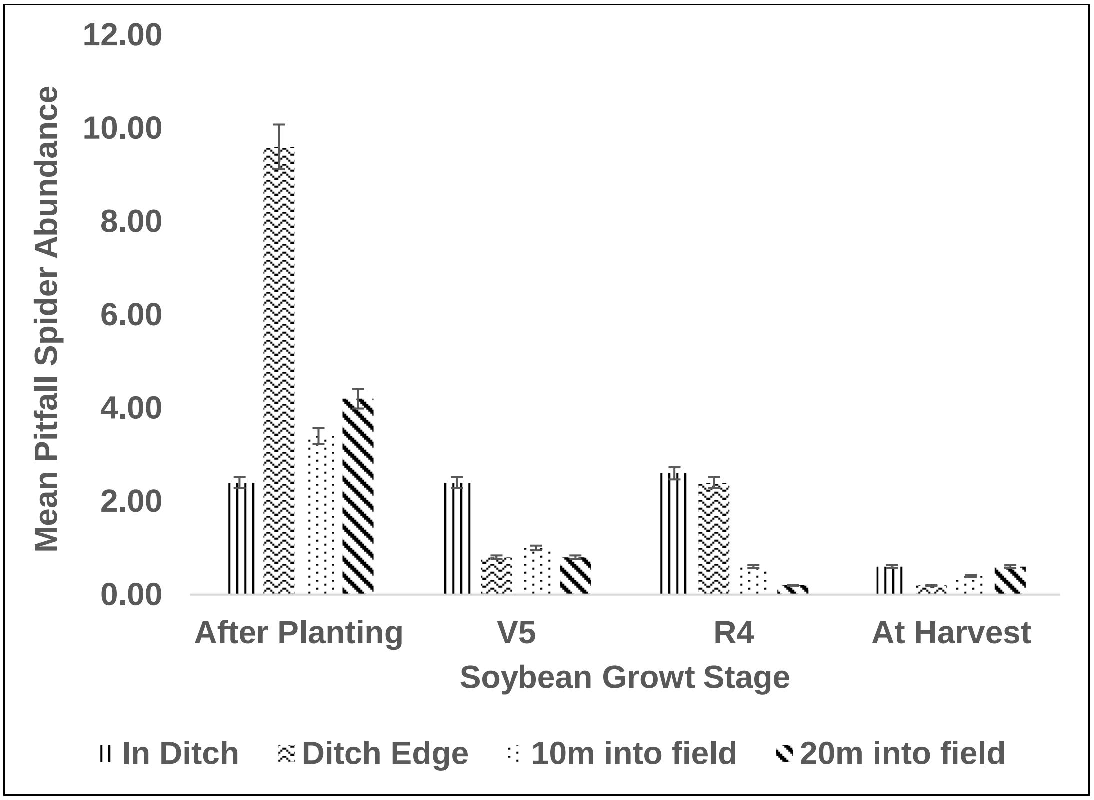

Figure 2.3 Mean pitfall spider abundances collected from each habitat type within each sampling period in 2018.

Table 2.2 Results for two-way ANOVA of the pitfall spider abundances collected in 2018, along with all significant post hoc interactions and the main effect post hoc comparisons. Sampling period and habitat type were used as main effects in the analysis.

Source	SS	df	MS	F-stat	p	Significant?
Sampling Period	233.54	3	77.85	17.06	<0.0001	Yes
Habitat Type	45.74	3	15.25	3.34	<0.05	Yes
Sampling Period x Habitat Type	141.71	9	15.75	3.45	<0.01	Yes
Error	292.00	64	4.56			
Total	712.99	79				

Significant Post Hoc Interaction	t-score	Critical Value for Interactions (α=0.05)
After Planting (In Ditch - Ditch Edge)	7.20	4.84
After Planting (Ditch Edge - 10m into field)	6.20	4.84
After Planting (Ditch Edge - 20m into field)	5.40	4.84

Post Hoc Comparisons of Main Effects	t-score	Critical Value (α=0.05)	Significant?
After Planting - V5	3.65	1.78	Yes
After Planting - R4	3.45	1.78	Yes
After Planting - At Harvest	4.45	1.78	Yes
V5 - R4	0.20	1.78	No
V5 - At Harvest	0.80	1.78	No
R4 - At Harvest	1.00	1.78	No
In ditch - Ditch Edge	1.25	1.78	No
In Ditch - 10m into field	0.65	1.78	No
In Ditch - 20m into field	0.55	1.78	No
Ditch Edge - 10m into field	1.90	1.78	Yes
Ditch Edge - 20m into field	1.80	1.78	Yes
10m into field - 20m into field	0.10	1.78	No

A total of 58 spiders were collected from the East drainage ditch and its neighboring croplands across all soybean growth stages and habitat types from foliar sweep sampling. The "after planting" sampling period produced the highest sweep spider abundance collected with 17 spiders, followed by the R4 sampling period with 11 spiders, the V5 sampling period with 8 spiders and the "at harvest" sampling period with 4 spiders. Of the habitat types sampled in 2018, the ditch edge habitat type produced the highest sweep spider abundance with 18 spiders across all sampling periods, followed by the in-ditch habitat type with 14 spiders, the "10m into field" habitat type with 7 spiders and the "20m into the field" habitat type with just 1 spider (Figure 2.4). Of the juvenile spiders collected from sweep sampling, the R4 sampling period produced the most with 4 juveniles, followed by the V5 sampling period with 3 juveniles and the "after planting" sampling period with 2 juveniles. No juvenile spiders were collected by sweep sampling during the "at harvest" sampling period. The two-way ANOVA performed to measure the variation between sweep spider abundances at each habitat type and sampling period generated significant differences in spider abundances as a result of both main effects (habitat type and sampling period) and the interaction of the two main effects (Two-Way ANOVA, Sampling Period Effect: {F=19.72, df=3, p<0.0001}, Habitat Type Effect:{F=4.49, df=3, p<0.01}, Interaction Effect:{F=3.20, df= 9, p<0.01}) . Through Tukey's HSD comparisons of these main effect interactions, I found that the significant differences between the sweep spider abundances of the in ditch vs. ditch edge, ditch edge vs, 10m into field, and ditch edge vs. 20m into field habitat types during the "after planting" sampling period were due to an interaction between the two main effects.

The only other significant differences found between the sweep spider abundances collected in 2018 were a result of the sampling period main effect, of which the “after planting” vs. V5, “after planting” vs. R4, and “after planting” vs. “at harvest” comparisons were significantly different (Table 2.3).

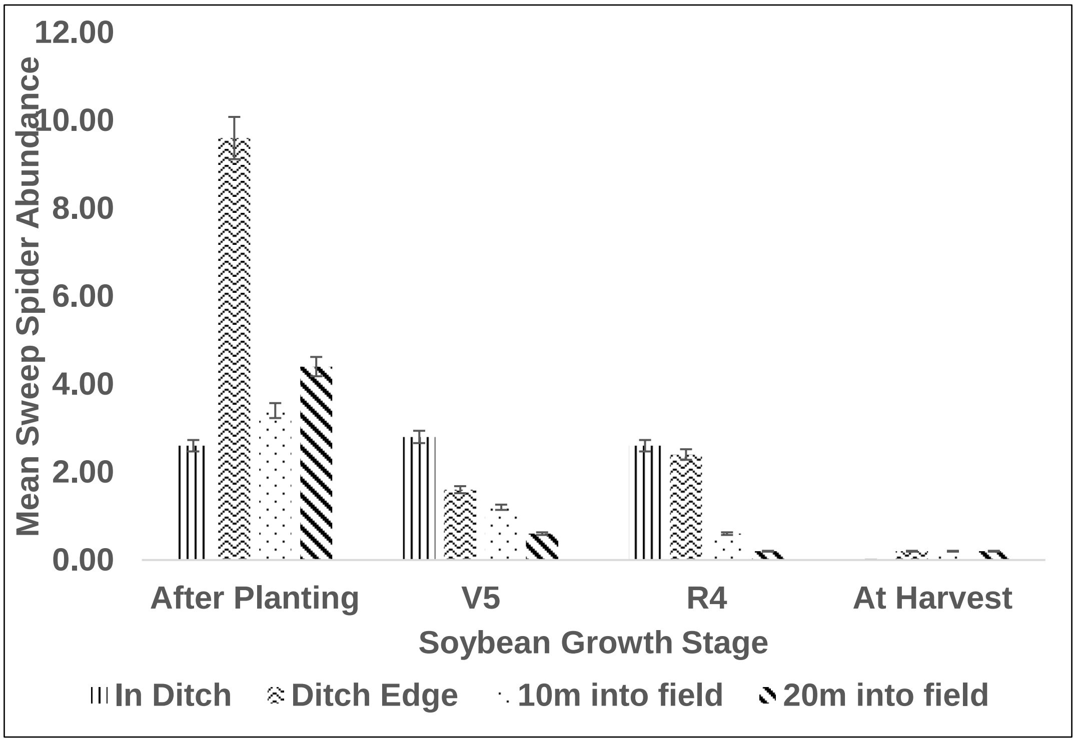

Figure 2.4 Mean spider abundance collected from sweep sampling across each habitat type within each sampling period in 2018.

Table 2.3 Results for two-way ANOVA of the sweep spider abundances collected in 2018, along with the significant post hoc interactions and main effect post hoc comparisons. Sampling period and habitat type were used as main effects in the analysis.

Source	SS	df	MS	F-stat	p	Significant?
Sampling Period	258.44	3	86.15	19.72	<0.0001	Yes
Habitat Type	58.84	3	19.61	4.49	<0.01	Yes
Sampling Period x Habitat Type	126.01	9	14.00	3.20	<0.01	Yes
Error	279.60	64	4.37			
Total	722.89	79				

Significant Post Hoc Interaction	t-score	Critical Value for Interaction (α=0.05)
After Planting (In Ditch - Ditch Edge)	7.00	4.73
After Planting (Ditch Edge - 10m into field)	6.20	4.73
After Planting (Ditch Edge - 20m into field)	5.20	4.73

Post Hoc Comparisons of Main Effects	t-score	Critical Value (α=0.05)	Significant?
After Planting - V5	3.45	1.75	Yes
After Planting - R4	3.55	1.75	Yes
After Planting - At Harvest	4.85	1.75	Yes
V5 - R4	0.10	1.75	No
V5 - At Harvest	1.40	1.75	No
R4 - At Harvest	1.30	1.75	No
In ditch - Ditch Edge	1.45	1.75	No
In Ditch - 10m into field	0.65	1.75	No
In Ditch - 20m into field	0.65	1.75	No
Ditch Edge - 10m into field	2.10	1.75	Yes
Ditch Edge - 20m into field	2.10	1.75	Yes
10m into field - 20m into field	0.00	1.75	No

Nine spider families encompassing 20 genera and species were identified across all sampling methods and sampling periods in 2018 (Table 2.4). The three most commonly identified spider genera during the 2018 sampling effort were *Pardosa milvina* with 85 observed specimens, *Tigrosa helluo* with 28 observed specimens, and *Zygoballus rufipes* with 24 observed specimens. Spider species present within each habitat type changed as the soybean growing season progressed (Table 2.5). Of the spider taxa identified from pitfall trapping, the R4 sampling period provided the highest species richness derived from pitfall trapping with 14 spider species across all habitat types, followed by the V5 sampling period with 10 spider species, the "after planting" sampling period with 7 spider species and the "at harvest" sampling period with 2 spider species (Figure 2.5). The two-way ANOVA performed to measure the variation between pitfall the spider species richness at each habitat type and sampling period generated significant differences in spider abundances only found significant differences due to the sampling period main effect (Two-Way ANOVA, Sampling Period Effect: F=9.71, df=3, p<0.0001).The only significant differences found between the pitfall spider species richness collected at each sampling period in 2018 were between the "after planting" vs. V5, "after planting" vs. R4, "after planting" vs. "at harvest", and V5 vs. R4 sampling periods (Table 2.6).

Table 2.4 Spider identifications from the East drainage ditch across all sampling dates during summer 2018. All individuals identified to species were adult specimens, as juvenile specimens were only identifiable to family.

Family	**Species**	**FFG**
Antrodiaetidae	*Antrodiaetus unicolor*	Burrowing
Anyphaenidae	*Hibana gracilis*	Foliage Runner
Araneidae	*Acanthepeira stellata*	Orb Weaver
	Araneus marmoreus	Orb Weaver
	Neoscona domiciliorum	Orb Weaver
Linyphiidae	*Erigone autumnalis*	Sheet Web Weaver
	Unidentified Juvenile	Sheet Web Weaver
Lycosidae	*Allocosa sublata*	Ground Runner
	Pardosa milvina	Ground Runner
	Pirata alachuus	Ground Runner
	Rabidosa rabida	Ground Runner
	Schizacosa avida	Ground Runner
	Tigrosa helluo	Ground Runner
	Trabeops auranticus	Ground Runner
	Unidentified Juvenile	Ground Runner
Salticidae	*Phiddipus regia*	Stalker
	Sitticus concolor	Stalker
	Zygoballus rufipes	Stalker
	Unidentified Juvenile	Stalker
Tetragnathidae	*Pachygnatha tristrata*	Orb Weaver
Thomisidae	*Misumessus oblongus*	Ambusher
	Xysticus ferox	Ambusher
Trachelidae	*Trachelas tranquillius*	Ambusher

Table 2.5 Spider taxa collected from the East drainage ditch and its neighboring soybean field in 2018 separated by the soybean growth stage and habitat type the spiders were collected in. The habitat types are abbreviated as the following: ID = In ditch, DE = Ditch edge, 10m = 10m from the ditch edge, 20m = 20m from the ditch edge.

Family	Species	After Planting	V5	R4	At Harvest
Antrodiaetidae	*Antrodiaetus unicolor*	-	-	10m	-
Anyphaenidae	*Hibana gracilis*	-	ID	ID	-
Araneidae	*Acanthepeira stellata*	-	-	-	-
	Araneus marmoreus	-	DE	-	-
	Neoscona domiciliorum	ID	ID, DE	DE	DE
Linyphiidae	*Erigone autumnalis*	-	-	20m	-
	Unidentified Juvenile	20m	ID, DE	-	-
Lycosidae	*Allocosa sublata*	DE, 10m, 20m	10m	DE	-
	Pardosa milvina	ID, DE, 10m	ID, 10m, 20m	ID, DE	10m, 20m
	Pirata alachuus	-	-	ID	-
	Rabidosa rabida	ID	ID	ID	-
	Schizacosa avida	ID, DE, 10m	DE	DE	DE, 20m
	Tigrosa helluo	ID, DE, 10m, 20m	ID, DE, 10m	ID, DE	ID, 10m, 20m
	Trabeops auranticus	10m	-	DE	-
	Unidentified Juvenile	-	ID	ID	-
Salticidae	*Phiddipus regia*	-	-	ID	-
	Sitticus concolor	ID, DE	ID, DE	ID, DE, 10m	10m, 20m
	Zygoballus rufipes	-	ID, DE	DE, 10m	-
	Unidentified Juvenile	ID	ID	ID	-
Tetragnathidae	*Pachygnatha tristrata*	-	ID	DE	-
Thomisidae	*Misumessus oblongus*	-	ID	-	-
	Xysticus ferox	-	-	-	ID
Trachelidae	*Trachelas tranquillius*	-	-	ID, DE	-

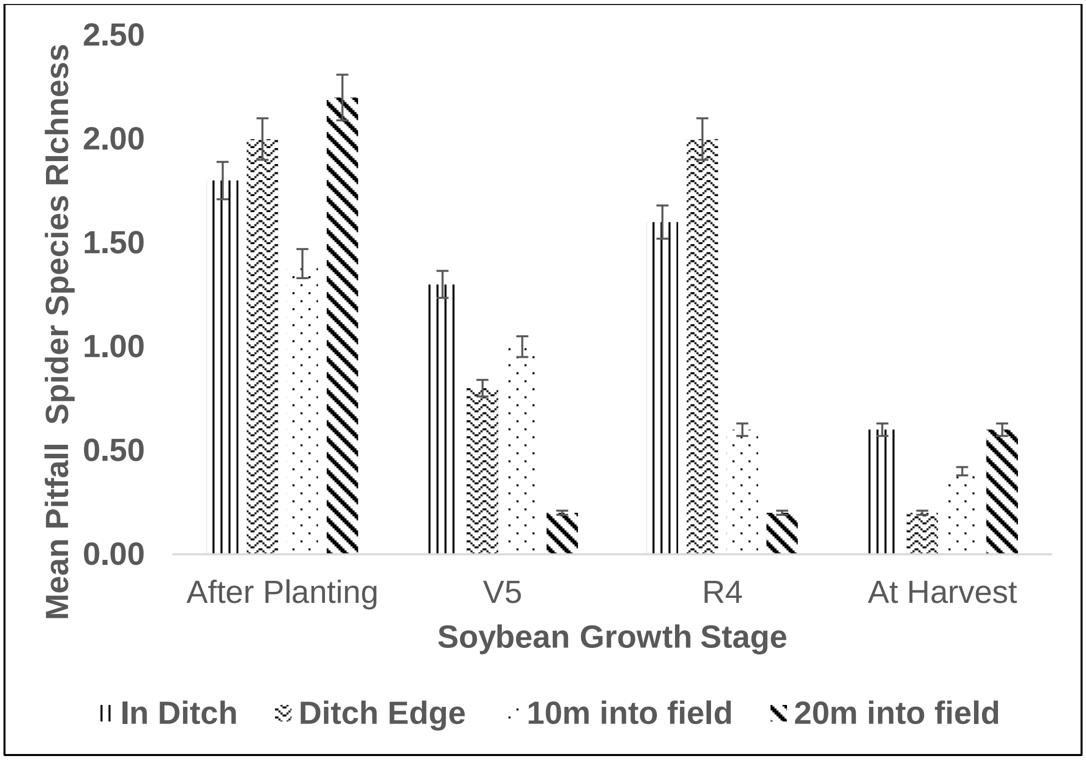

Figure 2.5 Mean spider species richness identified from pitfall samples at each habitat type and sampling period in 2018.

Table 2.6 Results for two-way ANOVA of the pitfall spider species richness identified from each habitat type and sampling period in 2018, along with the main effect post hoc comparisons. Sampling period and habitat type were used as main effects in the analysis.

Source	SS	df	MS	F-stat	p	Significant?
Sampling Period	21.30	3	7.10	9.71	<0.0001	Yes
Habitat Type	4.10	3	1.37	1.87	0.14	No
Sampling Period x Habitat Type	11.60	9	1.29	1.76	0.09	No
Error	46.80	64	0.73			
Total	83.80	79				

Post-Hoc Comparison	t-score	Critical Value (α=0.05)	Significant?
After Planting - V5	1.70	0.71	Yes
After Planting - R4	0.80	0.71	Yes
After Planting - At Harvest	1.40	0.71	Yes
V5 - R4	1.01	0.71	Yes
V5 - At Harvest	0.30	0.71	No
R4 - At Harvest	0.60	0.71	No

Of the spiders identified from sweep sampling in 2018, the R4 sampling period produced the highest spider species richness with 10 species across all habitat types, followed by the V5 sampling period with 8 species, the "after planting" sampling period with 3 species, and the "at harvest" sampling period with 2 species (Figure 2.6). The two-way ANOVA performed to measure the variation between sweep spider richness at each habitat type and sampling period generated significant differences in spider abundances as a result of both main effects (habitat type and sampling period) and the interaction of the two main effects (Two-Way ANOVA, Sampling Period Effect: {F=6.71, df=3, p<0.001}, Habitat Type Effect:{F=7.07, df=3, p<0.001}, Interaction Effect:{F=2.13, df= 9, p=0.04}). Through Tukey's HSD comparisons of these main effect interactions, I found that the significant differences between the sweep species richness of the in ditch vs. "20m into field" habitat types during the V5 sampling period, and the ditch edge vs, "20m into field habitat types during the R4 sampling period. Both significant findings were due to the interaction between the two main effects. Significant differences due to the sampling period main effect on sweep species richness were also found through Tukey's HSD, such as in the comparisons of the "after planting" vs R4 and the R4 vs. "at harvest sampling periods. Significant differences due to the habitat type main effect on sweep species richness were also found through Tukey's HSD, such as in the comparison of the in ditch vs. "10m into field" habitat types (Table2.7).

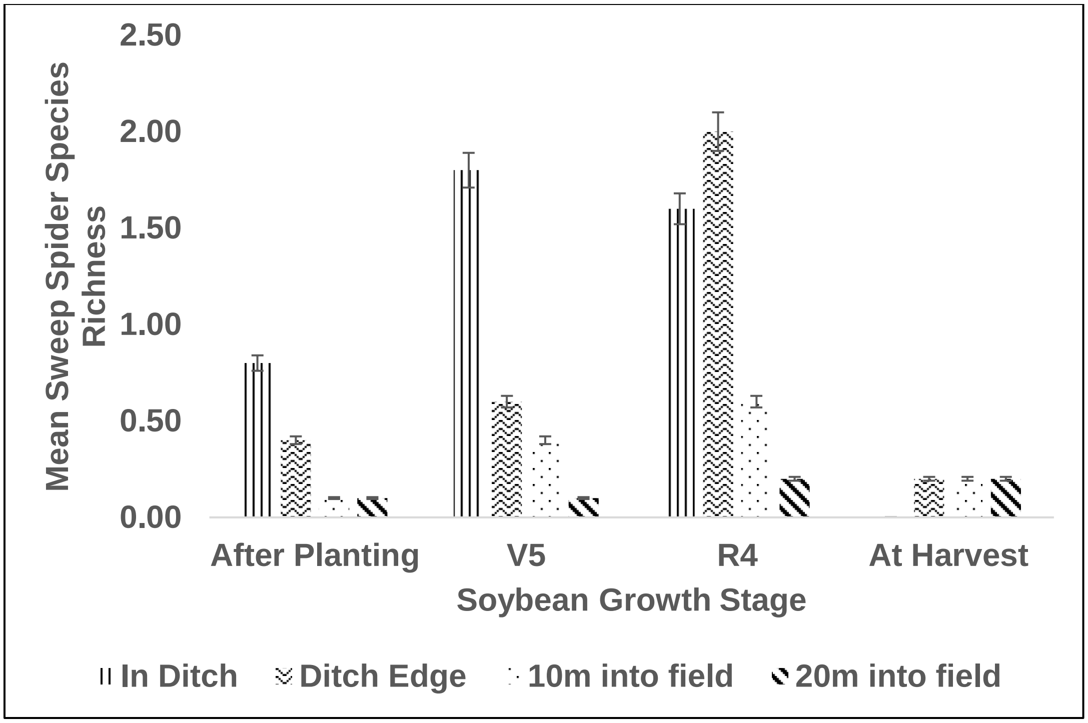

Figure 2.6 Mean spider species richness identified from sweep samples at each habitat type and sampling period in 2018.

Table 2.7 Results for two-way ANOVA of the sweep spider species richness identified from each habitat type and sampling period in 2018, along with all significant post hoc interactions and the main effect post hoc comparisons. Sampling period and habitat type were used as main effects in the analysis.

Source	SS	df	MS	F-stat	p	Significant?
Sampling Period	10.94	3	3.65	6.71	<0.001	Yes
Habitat Type	11.54	3	3.85	7.07	<0.001	Yes
Sampling Period x Habitat Type	10.41	9	1.16	2.13	0.04	Yes
Error	34.80	64	0.54			
Total	67.69	79				

Significant Post Hoc Interaction	t-score	Critical Value for Interaction (α=0.05)
V5(In Ditch - 20m into field)	1.80	1.67
R4 (Ditch Edge - 20m into field)	1.80	1.67

Post Hoc Comparisons of Main Effects	t-score	Critical Value (α=0.05)	Significant?
After Planting - V5	0.40	0.62	No
After Planting - R4	0.80	0.62	Yes
After Planting - At Harvest	0.15	0.62	No
V5 - R4	0.40	0.62	No
V5 - At Harvest	0.55	0.62	No
R4 - At Harvest	0.95	0.62	Yes
In ditch - Ditch Edge	0.15	0.62	No
In Ditch - 10m into field	0.75	0.62	Yes
In Ditch - 20m into field	0.95	0.62	Yes
Ditch Edge - 10m into field	0.50	0.62	No
Ditch Edge - 20m into field	0.70	0.62	Yes
10m into field - 20m into field	0.20	0.62	No

Three ditch experiment spider metrics, 2019

A total of 264 spiders were collected by pitfall trapping from all three drainage ditches and soybean fields across all sampling periods and habitat types in 2019. The “after planting” sampling period produced the highest pitfall spider abundance, with 82 spiders collected, followed by the “pre-planting” sampling period with 80 spiders, the R4 sampling period with 58 spiders and the V5 sampling period with 44 spiders. The “10m into field” habitat type produced the highest pitfall spider abundance with 71 spiders collected, followed by the ditch edge habitat type with 70 spiders, the in-ditch habitat type with 69 spiders, and the “20m into field” habitat type with 54 spiders. Of the juvenile spiders collected by pitfall trapping, the” pre-planting” sampling period produced the most with 16 juveniles, followed by the “after planting” and V5 sampling periods with 5 juveniles each. No juvenile spiders were collected by pitfall trapping during the R4 sampling period. Pitfall spider abundance varied within each habitat type across each sampling period, but the two-way ANOVA performed to assess the variation between these abundances saw no significant effect on pitfall spider abundance from either sampling period or habitat type (Two-Way ANOVA, Sampling Period Effect: {F=0.55, df=3, p=0.65}, Habitat Type Effect:{F=0.31, df=3, p=0.81}, Interaction Effect:{F=1.68, df= 9, p=0.11})

A total of 370 spiders were collected by sweep sampling from all three drainage ditches and soybean fields across all sampling periods and habitat types in 2019. The “after planting” sampling period produced the highest sweep spider abundance with 161 spiders collected, followed by the V5 sampling period with 114 spiders, the R4 sampling period with 79 spiders, and the “pre-planting” sampling period with 16 spiders. The ditch edge habitat type produced the highest sweep spider abundance with 146 spiders collected, followed by the in-ditch habitat type with 140 spiders, the “20m into field” habitat type with 44 spiders, and the “10m into field” habitat type with 40 spiders. Of the juvenile spiders collected by sweep sampling, the “after planting” sampling period produced the most with 11 juveniles, followed by the “pre-planting” sampling period with 3 juveniles, and the V5 and R4 sampling periods each with 2 juveniles. Sweep spider abundance within each habitat type changed as the soybean growing season progressed (Figure 2.7). The two-way ANOVA performed to analyze the variation in the sweep spider abundances between habitat types and sampling periods found significant differences as a result of both main effects (habitat type and sampling period) along with the interaction of the two main effects (Two-Way ANOVA, Sampling Period Effect: {F=11.82, df=3, p<0.0001}, Habitat Type Effect:{F=8.73, df=3, p<0.0001}, Interaction Effect:{F=3.86, df= 9, p<0.001}). Through Tukey’s HSD post hoc comparisons of the interaction of the main effects, I found that the comparisons of the in-ditch vs. “10m into field” and in-ditch vs. “20m into field” habitat types within the “after planting” sampling period were significantly different as a result of the interaction between the main effects. Significant differences were also found as a result of the sampling period main effect, such as in the post hoc comparisons of “pre-planting” vs “after planting” and “pre-planting vs. R4” sampling periods. Additionally, significant differences due to the habitat type main effect were found between the following habitat type comparisons: in-ditch vs. “10m into field”, in-ditch vs. “20m into field”, ditch edge vs. “10m into field” and ditch edge (Table 2.8)

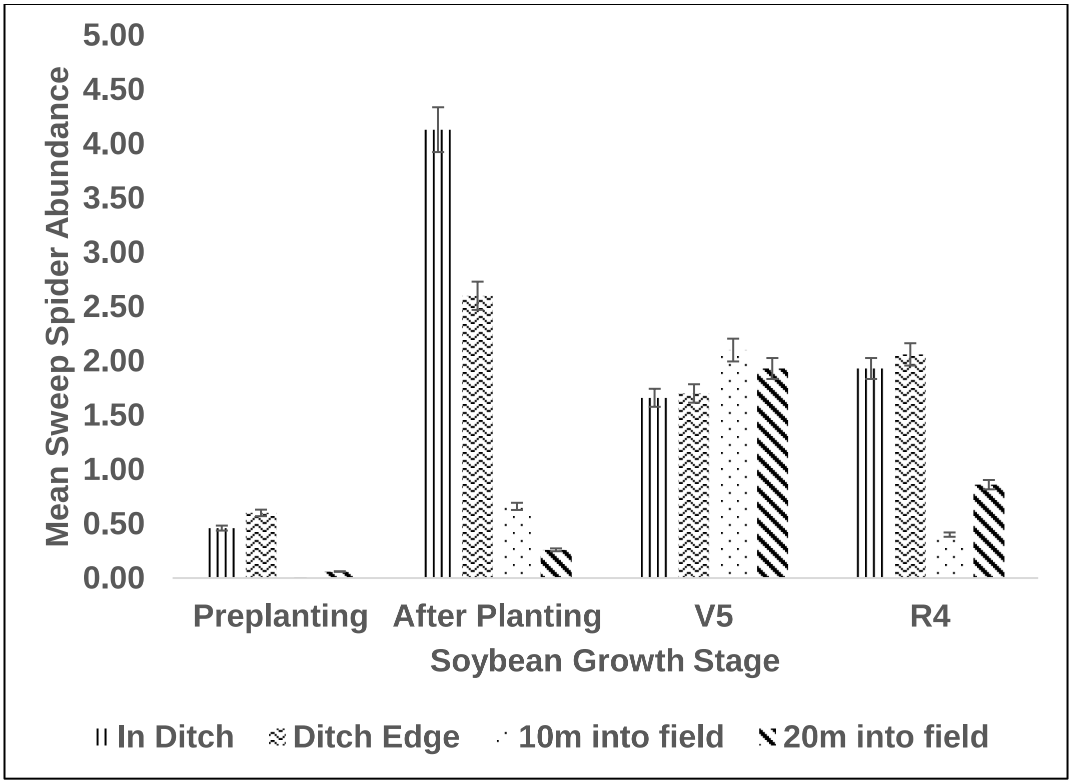

Figure 2.7 Mean spider abundance collected from sweep sampling across each habitat type within each sampling period in 2019.

Table 2.8 Results for two-way ANOVA of the sweep spider abundances collected in 2019, along with the significant post hoc interactions and main effect post hoc comparisons. Sampling period and habitat type were used as main effects in the analysis.

Source	SS	df	MS	F-stat	p	Significant?
Sampling Period	41.22	3	13.74	11.82	<0.0001	Yes
Habitat Type	30.45	3	10.15	8.73	<0.0001	Yes
Sampling Period x Habitat Type	40.36	9	4.48	3.86	<0.001	Yes
Error	74.39	64	1.16			
Total	186.42	79				

Significant Post Hoc Interaction	t-score	Critical Value for Interactions (α=0.05)
After Planting (In Ditch vs. 10m into field)	3.47	2.44
After Planting (In Ditch vs. 20m into field)	3.87	2.44

Post Hoc Comparison of Main Effects	t-score	Critical Value (α=0.05)	Significant?
Pre-planting vs. After Planting	1.63	0.90	Yes
Pre-planting vs. V5	1.57	0.90	Yes
Pre-planting vs. R4	0.58	0.90	No
After Planting vs. V5	0.06	0.90	No
After Planting vs. R4	0.60	0.90	No
V5 vs. R4	0.54	0.90	No
In ditch - Ditch Edge	0.31	0.90	No
In Ditch - 10m into field	1.26	0.90	Yes
In Ditch - 20m into field	1.27	0.90	Yes
Ditch Edge - 10m into field	0.95	0.90	Yes
Ditch Edge - 20m into field	0.96	0.90	Yes
10m into field - 20m into field	0.01	0.90	No

Fourteen spider families encompassing 30 genera and species were identified across all sampling methods, sampling periods and habitat types in 2019 (Table 2.9). The three most commonly identified spider genera during the 2019 sampling effort were *Pardosa milvina* (Family Lycosidae) with 157 observed specimens, *Sitticus concolor* (Family Salticidae) with 100 observed specimens, and *Zygoballus rufipes* (Family Salticidae) with 64 observed specimens. The presence of spider taxa in each habitat type changed as the soybean growing season progressed (Table 2.10). Of the spiders collected from pitfall trapping, the “pre-planting” sampling period produced the highest spider species richness with 11 species, followed by the V5 sampling period with 8 species, the “after planting” sampling period with 6 species and the R4 sampling period with 3 species. The two-way ANOVA performed to analyze the variation of the sweep spider species richness across habitat type and sampling period found no significant differences due to either variable (Two-Way ANOVA, Sampling Period Effect: {F=2.73, df=3, p=0.05}, Habitat Type Effect:{F=1.85, df=3, p=0.15}, Interaction Effect:{F=1.26, df= 9, p=0.12}).

Table 2.9 Spider identifications from all drainage ditches across all sampling dates during summer 2019. All individuals identified to species were adult specimens, as juvenile specimens were only identifiable to family or subfamily.

Family	Species	FFG
Agelenidae	*Agelenopsis pennsylvanica*	Sheet Web Weaver
Antrodiaetidae	*Antrodiaetus unicolor*	Burrowing
Anyphaenidae	*Hibana gracilis*	Foliage Runner
Araneidae	*Acanthepeira stellata*	Orb Weaver
	Araneus marmoreus	Orb Weaver
	Agriope aurantia	Orb Weaver
	Neoscona domiciliorum	Orb Weaver
Linyphiidae	*Erigone autumnalis*	Wandering Sheet Weaver
	Unidentified Juvenile	Wandering Sheet Weaver
Lycosidae	*Allocosa sublata*	Ground Runner
	Hogna frondicola	Ground Runner
	Pardosa milvina	Ground Runner
	Rabidosa rabida	Ground Runner
	Schizocosa avida	Ground Runner
	Tigrosa helluo	Ground Runner
	Trabeops aurantiacus	Ground Runner
	Unidentified Juvenile	Ground Runner
Oxyopidae	*Oxyopes salticus*	Stalker
Pisauridae	*Pisaurina dubia*	Ambusher
Salticidae	*Phiddipus regia*	Stalker
	Sitticus concolor	Stalker
	Zygoballus rufipes	Stalker
	Unidentified Juvenile	Stalker
Tetragnathidae	*Pachygnatha tristrata*	Orb Weaver
	Tetragnatha veriscolor	Orb Weaver
Theridiidae	*Parasteatoda tepidariorum*	Space Web Weaver
	Subbamily "Pholcommatinae"	Space Web Weaver
	Theridula opulenta	Space Web Weaver
	Unidentified Juvenile	Space Web Weaver
Theridosomatidae	*Theridosoma gemmosum*	Space Web Weaver
Thomisidae	*Mismenoides formosipes*	Ambusher
	Misumessus oblongus	Ambusher
	Xysticus ferox	Ambusher
Trachelidae	*Trachelas tranquillius*	Ambusher

Table 2.10 Spider taxa collected from all 3 drainage ditches and their neighboring soybean fields in 2019 separated by the soybean growth stage and habitat type the spiders were collected in. The habitat types are abbreviated as the following: ID = In ditch, DE = Ditch edge, 10m = 10m from the ditch edge, 20m = 20m from the ditch edge.

Family	Genus	Preplanting	After Planting	V5	R4
Agelenidae	*Agelenopsis pennsylvanica*	-	-	-	DE
Antrodiaetidae	*Antrodiaetus unicolor*	-	-	-	ID
Anyphaenidae	*Hibana gracilis*	-	-	10m	DE, 20m
Araneidae	*Acanthepeira stellata*	-	-	10m	ID, 20m
	Araneus marmoreus	-	-	ID, 10m, 20m	20m
	Agriope aurantia	-	-	20m	-
	Neoscona domiciliorum	ID	-	ID, 20m	ID, DE, 10m, 20m
Linyphiidae	*Erigone autumnalis*	20m	ID, DE, 10m, 20m	ID, DE	20m
	Unidentified Juvenile	ID, 20m	ID,10m, 20m	-	-
Lycosidae	*Allocosa sublata*	20m	-	-	-
	Hogna frondicola	DE	ID	-	-
	Pardosa milvina	ID, DE, 10m, 20m	ID, DE, 10m, 20m	ID, DE, 10m, 20m	ID, DE, 10m, 20m
	Rabidosa rabida	ID	ID, DE	ID, DE	ID, DE
	Schizocosa avida	ID, DE	-	ID	DE
	Tigrosa helluo	ID, DE	ID, DE, 10m	ID, DE, 20m	DE
	Trabeops aurantiacus	DE, 20m	-	-	-
	Unidentified Juvenile	ID, DE, 20m	ID, DE	ID, 10m	-
Oxyopidae	*Oxyopes salticus*	-	ID, DE	10m, 20m	ID, 10m, 20m
Pisauridae	*Pisaurina dubia*	ID	-		-
Salticidae	*Phiddipus regia*	-	-	-	ID
	Sitticus concolor	ID, DE	ID, DE	ID, DE. 20m	ID, DE, 20m
	Zygoballus rufipes	-	ID, DE	ID, 10m, 20m	ID, DE, 10m
	Unidentified Juvenile	DE	ID, DE	DE, 10m	DE
Tetragnathidae	*Pachygnatha tristrata*	DE, 20m	-	-	-
	Tetragnatha veriscolor	-	ID, DE	-	DE, 10m
Theridiidae	*Parasteatoda tepidariorum*	-	ID, DE	-	-
	Subbamily "Pholcommatinae"	DE, 20m	-	-	-
	Theridula opulenta	ID	ID, DE	-	-
	Unidentified Juvenile	DE	-	ID	-
Theridosomatidae	*Theridosoma gemmosum*	-	ID	-	-
Thomisidae	*Mismenoides formosipes*	ID, DE	-	10m	DE
	Misumessus oblongus	DE	-	ID, DE, 10m, 20m	ID, DE, 10m, 20m
	Xysticus ferox	ID, DE	ID, DE	ID, DE, 20m	ID
Trachelidae	*Trachelas tranquillius*	-	DE	-	DE

Of the spiders identified from sweep sampling in 2019, the V5 sampling period produced the highest spider species richness with 15 species, followed by the R4 sampling period with 11 species, the "after planting" sampling period with 8 species, and the "pre-planting" sampling period with 4 species. Spider species richness within each habitat type changed as the soybean growing season progressed (Figure 2.8). The two-way ANOVA performed to analyze the variation in species richness between habitat types and sampling periods found significant differences due to the main effects (habitat type and sampling period) and due to the interaction of these main effects (Two-Way ANOVA, Sampling Period Effect: {F=11.76, df=3, p<0.0001}, Habitat Type Effect: {F=9.36, df=3, p<0.0001}, Interaction Effect: {F=7.01, df= 9, p<0.0001}). Through Tukey's HSD post hoc comparisons of the interaction of the main effects, I found that post hoc comparisons of in-ditch vs. "10m into field", in-ditch vs. "20m into field", ditch edge vs. "10m into field" and ditch edge vs. "20m into field" habitat types within the "after planting" sampling period were significantly different as a result of the interaction between the main effects. Significant differences were also found as a result of the sampling period main effect, such as in the post hoc comparisons of "pre-planting" vs "after planting" and "pre-planting vs. R4" sampling periods. Additionally, significant differences due to the habitat type main effect were found between the following habitat type comparisons: in-ditch vs. "10m into field", in-ditch vs. "20m into field", ditch edge vs. "10m into field" and ditch edge vs. "20m into field" (Table 2.11).

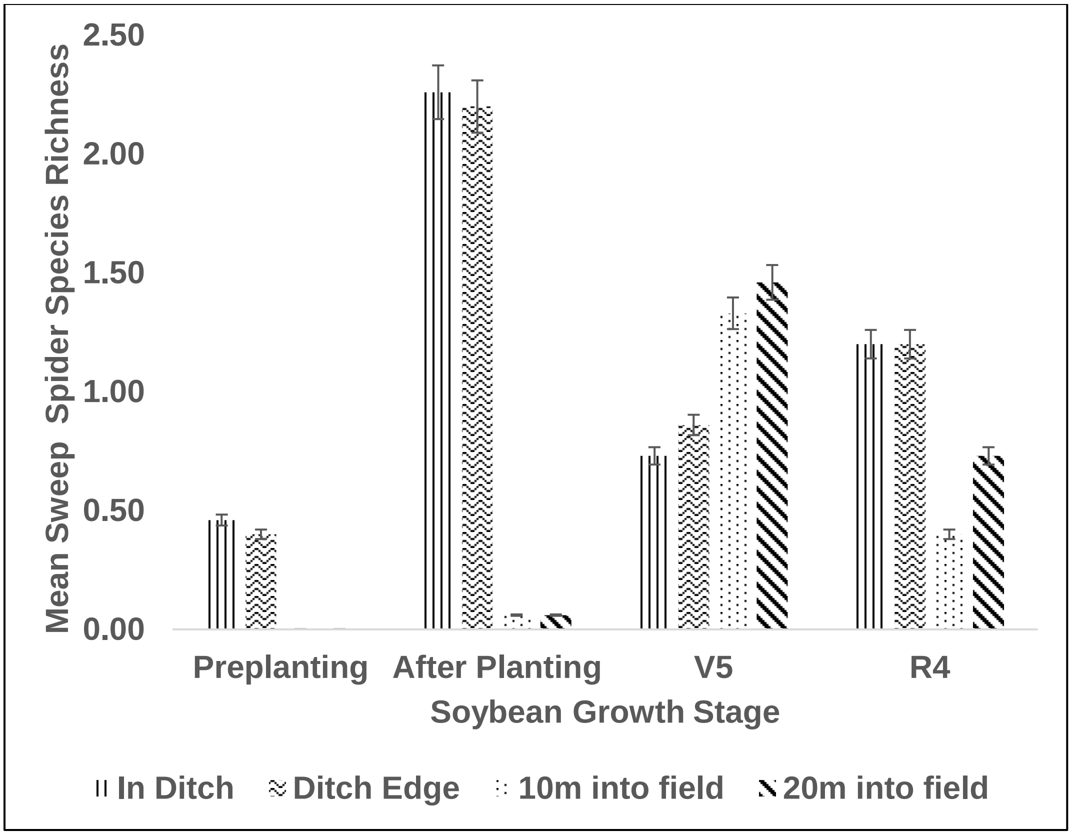

Figure 2.8 Mean spider species richness identified from sweep samples at each habitat type and sampling period in 2019.

Table 2.11 Results for the two-way ANOVA of the sweep spider species richness identified from each habitat type and sampling period in 2019, along with all significant post hoc interactions and the main effect post hoc comparisons. Sampling period and habitat type were used as main effects in the analysis.

Source	SS	df	MS	F-stat	p	Significant?
Sampling Period	11.09	3	3.70	11.76	<0.0001	Yes
Habitat Type	8.82	3	2.94	9.36	<0.0001	Yes
Sampling Period x Habitat Type	19.81	9	2.20	7.01	<0.0001	Yes
Error	20.11	64	0.31			
Total	59.83	79				

Significant Post Hoc Interaction	t-score	Critical Value for Interactions (α=0.05)
After Planting (In Ditch vs. 10m into field)	2.20	1.27
After Planting (In Ditch vs. 20m into field)	2.20	1.27
After Planting (Ditch Edge vs 10m into field)	2.14	1.27
After Planting (Ditch Edge vs. 20m into field)	2.14	1.27

Post Hoc Comparison of Main Effects	t-score	Critical Value (α=0.05)	Significant?
Pre-planting vs. After Planting	0.93	0.47	Yes
Pre-planting vs. V5	0.05	0.47	No
Pre-planting vs. R4	0.66	0.47	Yes
After Planting vs. V5	0.05	0.47	No
After Planting vs. R4	0.27	0.47	No
V5 vs. R4	0.05	0.47	No
In ditch - Ditch Edge	0.01	0.47	No
In Ditch - 10m into field	0.71	0.47	Yes
In Ditch - 20m into field	0.60	0.47	Yes
Ditch Edge - 10m into field	0.72	0.47	Yes
Ditch Edge - 20m into field	0.61	0.47	Yes
10m into field - 20m into field	0.11	0.47	No

The Bray-Curtis dissimilarity matrices generated for each habitat type within each sampling period were calculated from the taxa richness and relative abundance of the spider assemblages in each habitat type at each sampling period. For the "pre-planting" sampling period, the spider assemblages located in the ditch edge and "20m into the field" habitat types were the most similar, with 57.50% Bray-Curtis dissimilarity between the assemblages. The most dissimilar habitat types during the "pre-planting" habitat type were the ditch edge and "10m into the field" spider assemblages, with 84.61% Bray-Curtis dissimilarity. For the "after planting" sampling period, the "10m into the field" and "20m into the field" habitat types contained the most similar spider assemblages, with only 11.44% Bray-Curtis dissimilarity between the assemblages. The most dissimilar habitat types during the "after-planting" sampling period were the in-ditch and "20m into the field" habitat types, with 90.70% Bray-Curtis dissimilarity. For the V5 sampling period, the in-ditch and ditch edge habitat types contained the most similar spider assemblages, with only 31.41% Bray-Curtis dissimilarity between the assemblages. The most dissimilar habitat types during the V5 sampling period were the in-ditch and "10m into the field" habitat types, with 65.90% Bray-Curtis dissimilarity. For the R4 sampling period, the in ditch and ditch edge habitat types contained the most similar spider assemblages, with only 42.90% Bray-Curtis dissimilarity between the assemblages. The most dissimilar habitat types during the R4 sampling period were the "10m into the field" and "20m into the field" habitat types, with 90.90% Bray-Curtis dissimilarity (Table 2.12).

Table 2.12 Bray-Curtis dissimilarity matrix percentages between all habitat types across all soybean growth stages in 2019. Higher percentages indicate less similar spider diversity and relative abundances between the two habitat types.

Pre-Planting	**In Ditch**	**Ditch Edge**	**10m into field**	**20m into field**
In Ditch	-	69.90%	74.40%	74.00%
Ditch Edge	-	-	84.60%	57.70%
10m into field	-	-	-	83.30%
20m into field	-	-	-	-
After Planting	**In Ditch**	**Ditch Edge**	**10m into field**	**20m into field**
In Ditch	-	21.80%	78.80%	90.70%
Ditch Edge	-	-	78.20%	81.80%
10m into field	-	-	-	11.40%
20m into field	-	-	-	-
V5	**In Ditch**	**Ditch Edge**	**10m into field**	**20m into field**
In Ditch	-	31.40%	65.90%	53.10%
Ditch Edge	-	-	65.80%	58.40%
10m into field	-	-	-	33.30%
20m into field	-	-	-	-
R4	**In Ditch**	**Ditch Edge**	**10m into field**	**20m into field**
In Ditch	-	42.90%	58.00%	58.50%
Ditch Edge	-	-	56.80%	81.90%
10m into field	-	-	-	90.90%
20m into field	-	-	-	-

Plant diversity, prey abundance, and environmental conditions, 2019

A total of 16 plant families were identified across all drainage ditches and sampling periods in 2019, encompassing 20 genera (Table 2.13). The three most commonly identified plant families in my 2019 sampling effort were Asteraceae, Anacaridaceae, and Typhaceae. The number of plant genera identified within a given drainage ditch during any given sampling period ranged from 4-10 plant genera. *Solidago* (Family Asteraceae), *Toxicodendron* (Family Anacaridaceae) and *Typha* (Typhaceae) were the most commonly identified plant genera across all three drainage ditches, which were observed 68, 52 and 36 times respectively within the 120 Daubenmire cover quadrats taken across all drainage ditches over the course of the soybean growing season. The mean percent coverage provided by these 3 genera across the 3 drainage ditches ranged from 28% (*Toxicodendron*) to 55% (*Solidago*). Other plant genera also provided ample coverage in the drainage ditches but were less common in our collection (Table 2.14). The rank abundance curves generated for each sampling period depict the species richness and evenness of the plant assemblages inhabiting the 3 drainage ditches, along with how these metrics change as the soybean growth season progresses. While the Mid and South drainage ditches appeared to remain relatively even throughout the growing season, the plant assemblage of the Far drainage ditch became less evenly distributed as time progressed. Plant taxa richness and evenness of each drainage ditch varied greatly between the drainage ditches and sampling periods (Figures 9-12).

Table 2.13 Plant identifications from all drainage ditches across all sampling dates during summer 2019.

Family	**Genus**
Amaryllidacae	*Allium*
Anacardiaceae	*Toxicodendron*
Apiaceae	*Daucus*
Apocynaceae	*Ascelpias*
Asteraceae	*Eutrochium*
	Solidago
Balasminaceae	*Impatiens*
Caprifoliaceae	*Lonicera*
Fabaceae	*Trifolium*
Iridaceae	*Iris*
Phytolaccaceae	*Phytolacca*
Poaceae	*Festuca*
	Microstegium
	Phragmites
	Triticum
Ranunculaceae	*Ranunculus*
Sapindaceae	*Acer*
Smilaceae	*Smilax*
Typhaceae	*Typha*
Urticaceae	*Urtica*

Table 2.14 The 10 most commonly identified plant genera and their mean coverage across all ditches and sampling dates collected during the summer 2019 sampling effort.

Family	**Genus**	**Number of Observations**	**Mean % Coverage**
Asteraceae	*Solidago*	68	55.0 ± 4.1
Anacardiaceae	*Toxicodendron*	52	28.0 ± 4.6
Typhaceae	*Typha*	36	32.0 ± 5.5
Poaceae	*Triticum*	23	9.9 ±3.6
Asteraceae	*Eutrochium*	22	54.0 ± 6.0
Apiaceae	*Daucus*	14	28.9 ± 9.1
Phytolaccaceae	*Phytolacca*	14	27.3 ± 18.3
Smilacaeae	*Smilax*	14	22.9 ± 7.7
Urticaceae	*Urtica*	12	29.4 ± 8.0
Poaceae	*Festuca*	11	37.0 ± 9.7

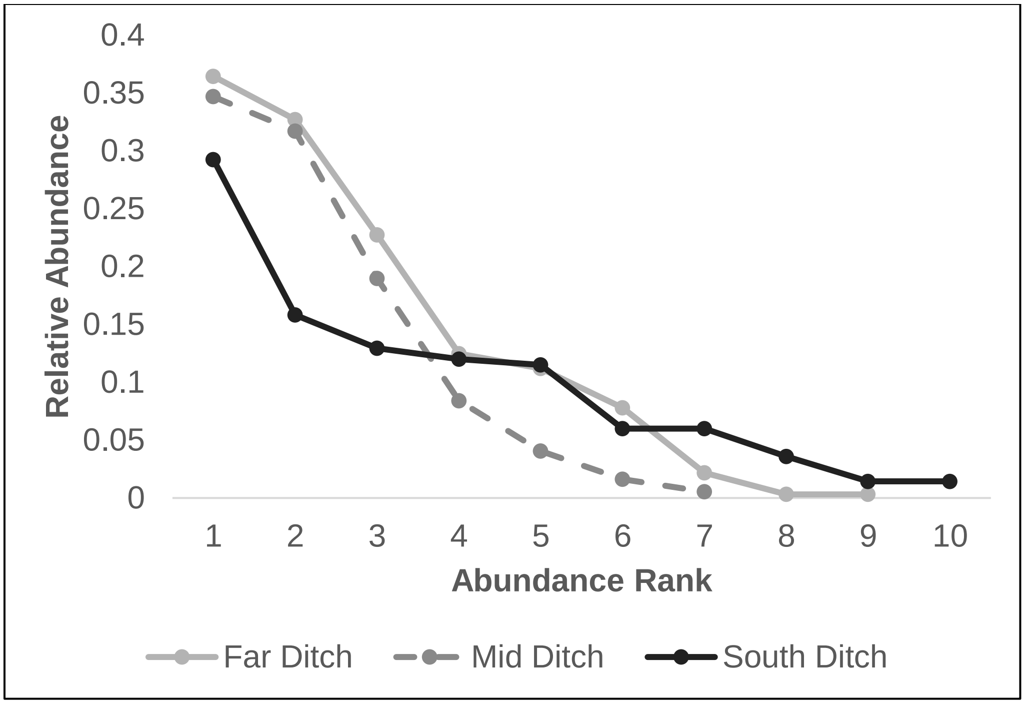

Figure 2.9 Rank abundance curve of the plant assemblage observed at all three ditches during the “pre-planting” sampling period.

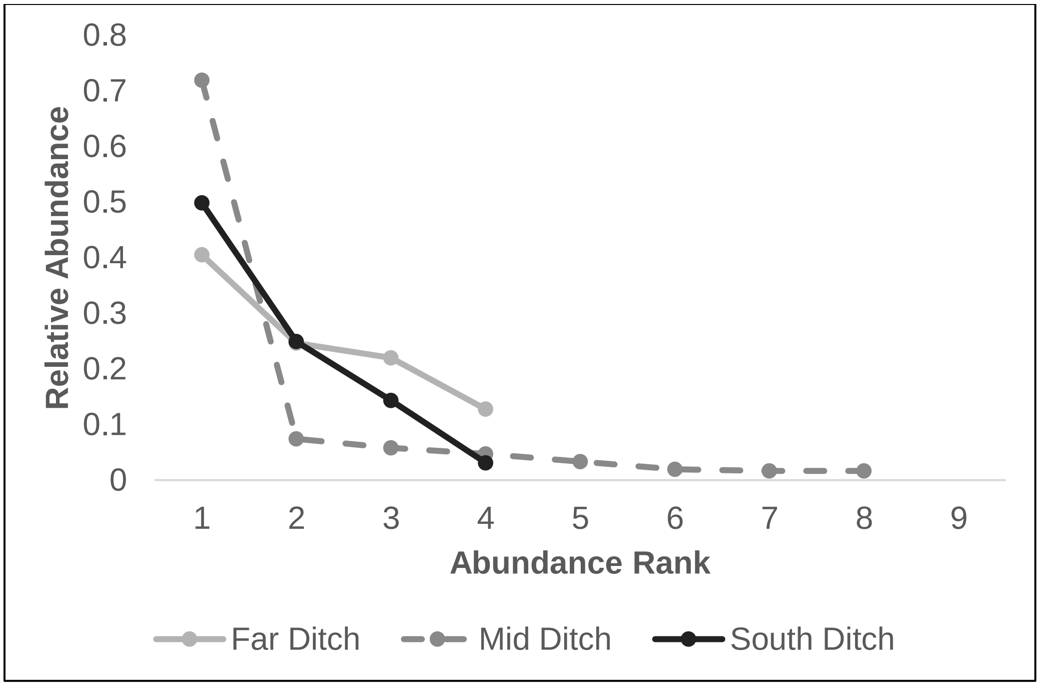

Figure 2.10 Rank abundance curve of the plant assemblage observed at all three ditches during the “after-planting” sampling period.

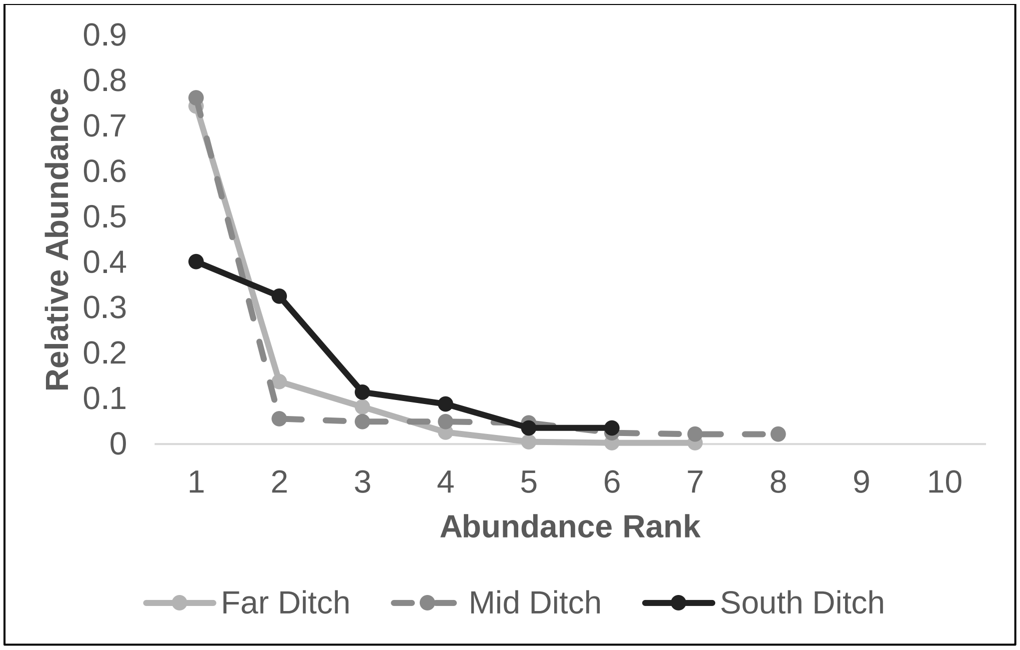

Figure 2.11 Rank abundance curve of the plant assemblage observed at all three ditches during the V5 sampling period.

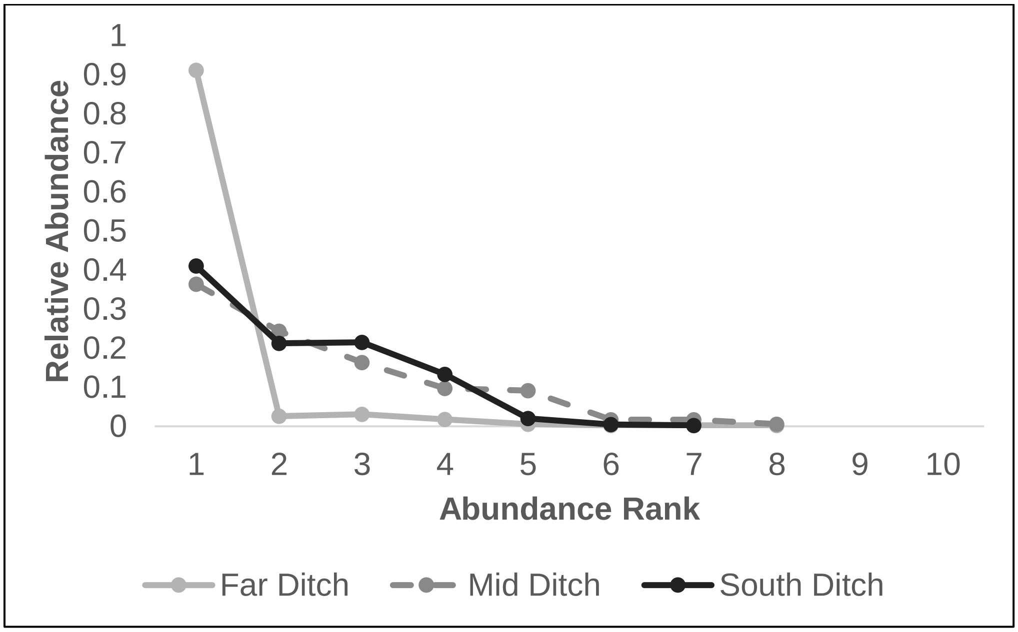

Figure 2.12 Rank abundance curve of the plant assemblage observed at all three ditches during the R4 sampling period.

The non-spider arthropods collected from each sampling method were identified and counted in order to determine the availability of prey resources in each habitat type during each sampling period. Non-spider arthropod counts were averaged for each habitat type with each sampling period and compared to mean spider abundances within those habitats and sampling periods. The linear regression analysis used to analyze the effect of prey abundance on spider abundance across all drainage ditches and sampling methods found a significant positive association between both variables (Figure 2.13, Linear Regression, R^2=0.40, $p<0.05$). Additionally, the linear regression analysis used to analyze the effect of plant diversity on prey abundance in drainage ditch habitats (in-ditch and ditch edge) also found a significant association between the variables (Figure 2.14, Linear Regression, R^2=0.59, $p<0.05$). Mean prey abundance calculated for each habitat type within each sampling period from the 3 drainage ditches varied greatly between habitat types and sampling periods. The in-ditch habitat type steadily lost prey abundance as the growing season progressed, but the ditch edge, “10m into the field” and “20m into the field” habitat types varied greatly throughout the course of the growing season (Figure 2.15).

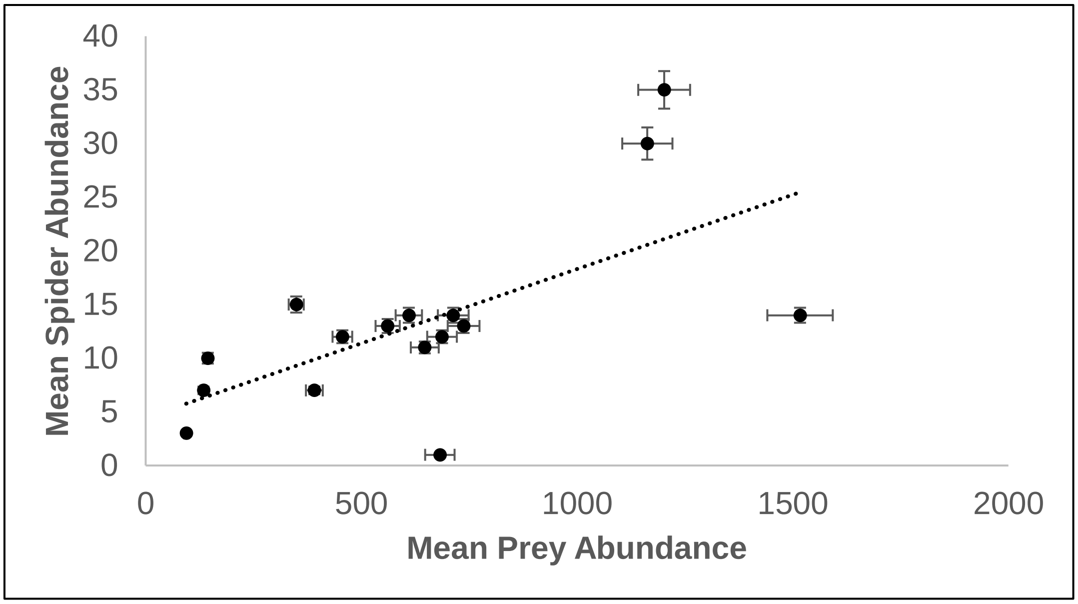

Figure 2.13 Linear regression analysis of the effect of prey abundance on spider abundance across all drainage ditches and sampling methods. A significant positive association between the two variables ($p<0.05$) was calculated at $\alpha=0.05$.

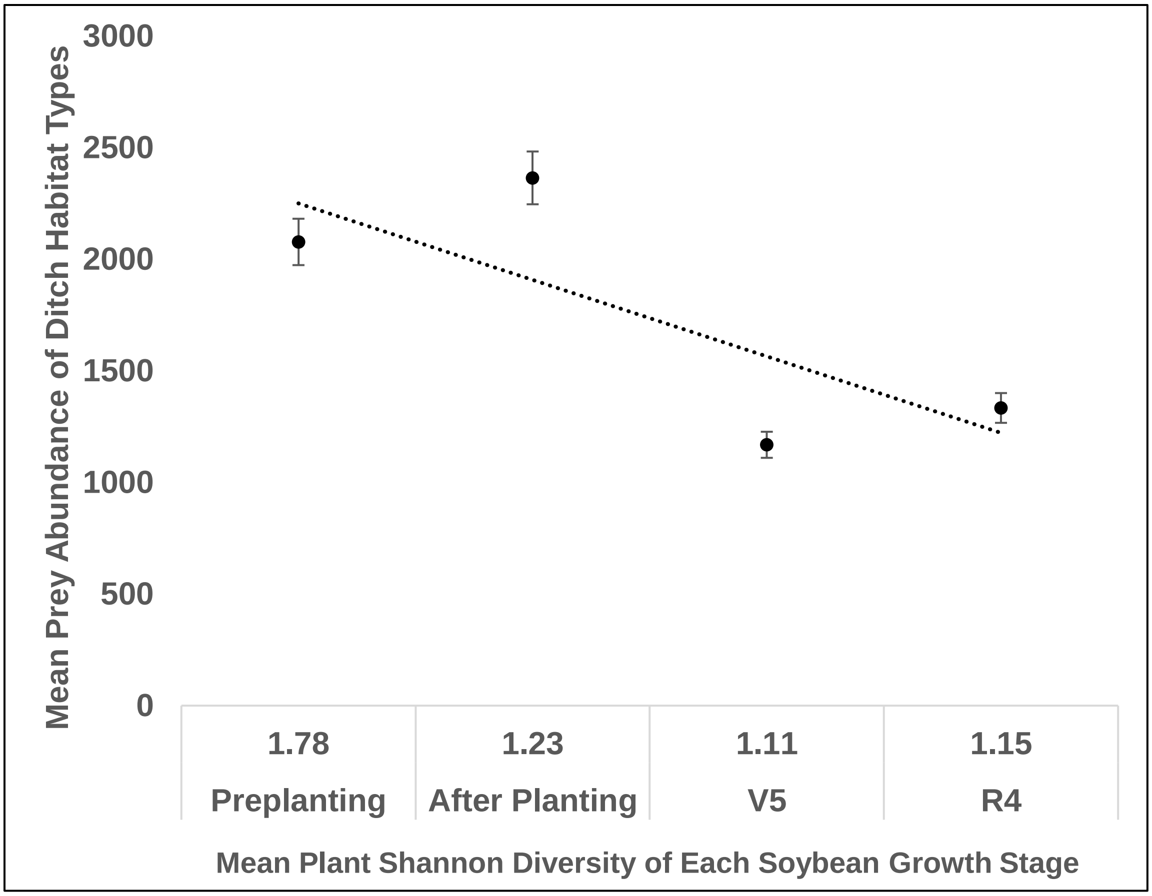

Figure 2.14 Linear regression analysis of the effect of mean plant Shannon diversity on mean prey abundance in drainage ditch habitat types. A significant negative association between the two variables ($p<0.05$) was calculated at $\alpha=0.05$.

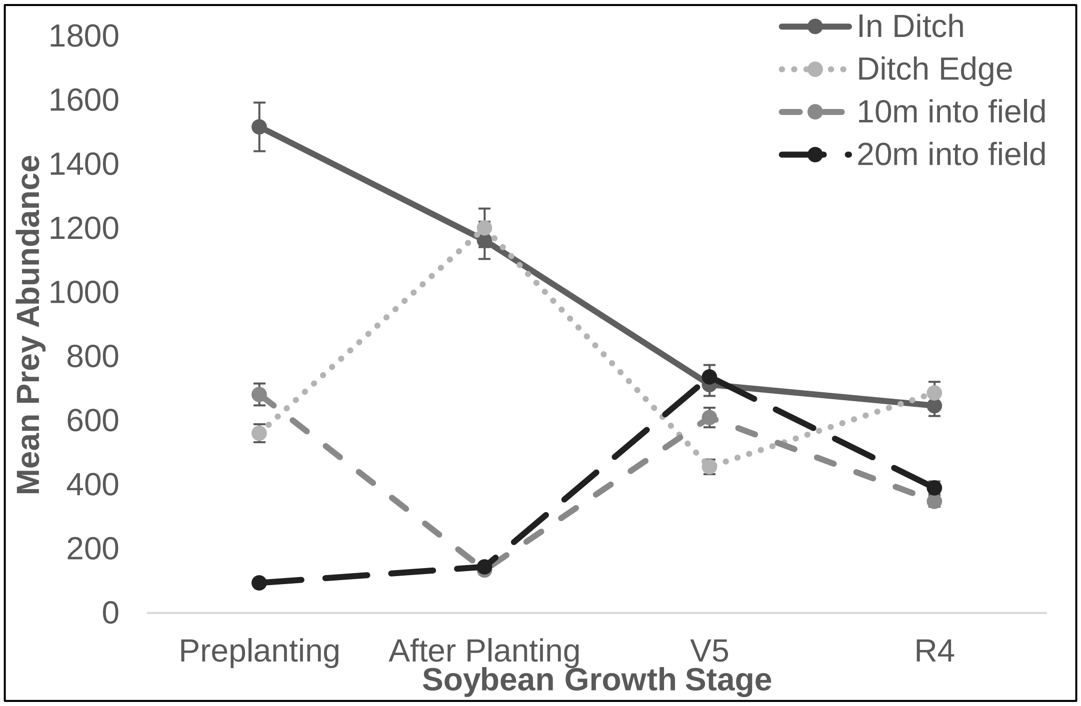

Figure 2.15 The variation in mean prey abundance within each habitat type between each soybean growth stage sampled. Mean prey abundance between habitat types became more similar as the soybean growing season progressed.

Ground-level humidity and temperature conditions collected from each drainage ditch and its neighboring cropland averaged from the 30 readings taken by the humidity and temperature sensors at each drainage ditch on one day during each sampling period. The highest calculated mean ground temperature inside a drainage ditch was recorded during the “after-planting” sampling period, with a mean ground temperature of 46.30 ± 1.90 degrees Celsius. The highest recorded mean ground temperature inside a neighboring soybean field was also recorded during the “after-planting” sampling period, with a mean ground temperature of 44.50 ± 6.20 degrees Celsius. Both the highest in-ditch and in-field mean relative humidifies were recorded from the “pre-planting”, with a mean relative humidity of 97.70±0.70% in the drainage ditch and 94.00 ± 1.80% in the soybean field. After comparing the temperature and humidity data recorded in the drainage ditches and their neighboring croplands through student’s t analyses, I found no significant differences between the in-ditch and in-field temperature and relative humidity at any drainage ditch across all sampling periods at $\alpha = 0.05$ (Table 2.15, Humidity t-test: {t=0.20, df = 1 p=0.43}, Temperature t-test: {t=0.33, df=1, p=0.39).

Table 2.15 Ground-level temperature and relative humidity observed at all 3 drainage ditches and in their neighboring soybean fields.

Soybean Growth Stage	Ditch	Mean In Ditch Ground Temperature (°C)	Mean In Field Ground Temperature (°C)	Mean In Ditch Relative Humidity (%)	Mean In Field Relative Humidity (%)
Pre-Planting	Far	14.50 ± 0.70	15.20 ± 0.80	94.60 ± 2.30	92.70 ±3.20
	Mid	18.10 ± 1.50	16.60 ± 1.00	97.70 ± 0.70	90.30 ± 2.40
	South	14.60 ± 0.20	15. 60 ± 0.60	98.90 ± 0.10	94.00 ± 1.80
After Planting	Far	46.30 ± 1.90	44.50 ± 6.20	36.80 ± 3.60	37.50 ± 8.70
	Mid	34.70 ± 1.20	40.90 ± 0.80	61.60 ± 4.10	38.10 ± 1.30
	South	41.40 ± 1.50	39.80 ± 1.20	41.40 ± 3.90	46.30 ± 2.70
V5	Far	44.00 ± 2.20	44.50 ± 2.10	36.60 ± 4.70	33.50 ± 4.40
	Mid	36.90 ± 7.40	32.10 ± 2.20	50.30 ± 14.00	57.50 ± 5.90
	South	31.60 ± 2.90	33.00 ± 1.50	61.60 ± 8.20	53.90 ± 4.60
R4	Far	26.10 ± 0.50	26.10 ± 0.40	65.30 ± 3.00	53.30 ± 1.20
	Mid	23.60 ± 0.40	24.20 ± 0.30	71.60 ± 2.10	78.50 ± 5.10
	South	24.70 ± 0.30	26.60 ± 0.70	62.60 ± 1.50	54.40 ± 1.80

Discussion

Agricultural drainage ditches may serve as sources of beneficial spiders as adjacent soybeans develop through the growing season (Oberg et al. 2007). Here, I sought to determine to what extent the composition of spider assemblages in drainage ditches influence spider assemblages in nearby croplands. Specifically, my research aimed to assess how spider assemblages in drainage ditches and their neighboring croplands change throughout a soybean growing season, determine what spiders colonize croplands from drainage ditches, and identify what environmental conditions influence spider assemblages and spider colonization of croplands from drainage ditches. My results demonstrate that the spider assemblages in drainage ditches and soybean fields change due to the progression of the soybean growing cycle, and the ditch-dwelling spiders colonize soybean fields as they grow over time.

From the results of the 2018 and 2019 field experiments, I discovered that spider assemblages in both drainage ditches and their neighboring croplands differ in both species richness and abundance throughout the soybean growth cycle. One important aspect to consider when assessing spider assemblages in drainage ditches is how spiders were collected. Spiders collected by pitfall trapping mainly characterize the ground-dwelling spider assemblages, while sweep sampling characterizes the foliar-dwelling spider assemblages in drainage ditches, which warrants separate discussion on the two types of spider assemblages. For example, many significant trends observed in my study only hold true for foliar-dwelling spider assemblages, and not for ground-dwelling spider assemblages. While significant differences in the spider abundances collected by pitfall traps between sampling periods and habitat types were observed during the 2018 sampling season, these trends were not repeated in the 2019 sampling season. This difference in significance is likely due to the small sample size of the 2018 sampling season, a factor that can often overstate significant trends, which makes sense in this case, as the 2018 sampling season was a small, preliminary sampling effort compared to the 2019 sampling season (Royall 1986).

Across both sampling years, the abundances of the foliar-dwelling spiders in drainage ditches were significantly greater than those in croplands during the early stages of the soybean growing season. As the soybean growing season progressed, the abundance of foliar-dwelling spiders in each habitat type became more similar to one another, and no longer significantly different in my analysis. The significance of this trend in spider abundances indicates a shift in spider abundance, in which spiders are leaving drainage ditches and moving to neighboring soybean fields, likely to take advantage of less competition and new prey resources, a trend that was also observed in a study on spider movement to soybean fields from other uncropped habitats (Belltramo et al. 2006). While this trend in spider abundance is most evident in the 2019 sampling season, traces of the trend are still present in the 2018 sampling season, but with far fewer numbers of spiders. The reason for this disparity in spider abundance between the sampling years is likely a result of the difference in annual weather effecting the farm. Spider abundances collected from the East drainage ditch and its neighboring soybean field in 2018 were lower than those collected from any of the three ditches and fields sampled in 2019. This difference in abundance from 2018 and 2019 was likely due to delayed soybean plantings in the neighboring croplands due to an abnormally rainy early summer, which in turn pushed the R4 and “at harvest" sampling dates back to the colder autumn months, where spiders are generally less active and lessen in abundance (Aitchison 1987). This rationale is especially likely given that all four drainage ditches were located at the same farm, managed in a similar manner and sampled with the same approach. Along with spider abundance, the spider species found in drainage ditches and their neighboring croplands seems to be dependent on whether the spider species is considered a ground-dwelling or foliar dwelling species. Spiders that are more associated with wandering or living on the ground as lycosids, linyphiids and anyphaenids, appear to be less impacted by the presence of crop development in neighboring croplands. While these ground-dwelling spiders vary in abundance and diversity inside croplands throughout the soybean growing season, very few significant differences were found in the two-way ANOVAs of either metric as a result of soybean growth stage or habitat type. This evidence suggests that ground dwelling spider assemblages are not significantly influenced by the higher plant diversity in drainage ditches or the progression of the soybean growing season. Other studies on ground dwelling spiders have reported that higher plant diversity doesn't correlate to higher species richness in ground dwelling spiders, which is instead driven by the microhabitats available in a given ecosystem (Ziesche and Roth 2008).

In contrast, foliar dwelling spiders, such as salticids, oxyopids, and various orb-weaving families, appear to depend heavily on crop development to inhabit the croplands neighboring drainage ditches. These foliar-dwelling spiders are nearly nonexistent in soybean fields prior to the vegetative stages of the soybean growing season, and when they are more abundant later in the summer, seem to predominantly be the same taxa of spiders found in drainage ditches early in the growing season. The two-way ANOVAs performed to assess differences in the abundance and species richness of the foliar dwelling spider assemblages produced significant differences for both metrics between drainage ditch associated habitat types (in-ditch and ditch habitats) and cropland associated habitat types (10m into field and 20m into field habitats). Additionally, the two-way ANOVAs of the same metrics also found significant differences between the early soybean growth stages (pre-planting and after planting sampling periods) and the later growth stages (V5 and R4 sampling periods) for foliar dwelling spiders. Both two-way ANOVAs reflect trends in spider colonization that have been previously observed in soybean spider assemblages, where the foliar-dwelling spiders do not overwinter in harvested soybean fields, and instead colonize the soybeans from nearby uncropped areas on the farm (LeSar and Unzicker 1978). All together, these significant findings suggest that foliar dwelling spider assemblages are more abundant and diverse in drainage ditches early in the soybean growing season when compared to fields, but ditch and soybean spider assemblages become more similar in diversity and abundance as the growing season progresses.

Within the four habitat types defined and sampled in both sampling years, the data demonstrate interesting patterns of spider distribution across the habitat types. Some spider taxa seem to be cosmopolitan within drainage ditches and their neighboring croplands, appearing in all habitat types during every sampling period. The best example of a cosmopolitan spider in this system would be the wolf spider *Pardosa milvina,* which appears in virtually every habitat type during every sampling period, predominantly in pitfall trap samples. As a species, *Pardosa milvina* has previously been touted for its potential to colonize croplands from outside sources, to the extent that they are so prevalent that becomes difficult to discern their source (Marshall et al. 2002). On the other hand, some spider taxa appear to only inhabit the drainage ditch and ditch edge habitats and were never collected in the neighboring soybean fields. Another lycosid spider, *Rabidosa rabida,* is an example of this type of distribution, as it was only collected from the in-ditch and ditch edge habitat types throughout the entire growing season. However, this type of narrow distribution in the drainage ditch-cropland ecosystem likely means that these less colonizing spiders are not good biocontrol candidates, as they are less likely to encounter pest prey items in the nearby croplands.

In order for drainage ditches to be established as a potential source of natural enemies for nearby croplands, natural enemies need to inhabit the ditch early in a crop's growth cycle and spread to the croplands as the crop grows. Of the spiders collected in drainage ditches and neighboring croplands in 2018 and 2019, a few spider species stand out as potential useful natural enemies. An exemplar species for this role in the ditch-cropland ecosystem would be the salticid spider, *Sitticus concolor*. These jumping spiders are found in drainage ditches as adult specimens early in the soybean growing season, only to be predominantly found as adults in the cropland habitat types later in the growing season. In effect, this spider species is likely colonizing the croplands for their survival resources, making the spider species more likely to consume agricultural pests in croplands. Other spider species, such as *Zygoballus rufipes,* also seem to follow the same distribution pattern as *S. conolor,* except *Zygoballus rufipes* colonizes the croplands later in the growing season and does not move as deeply into the croplands. However, while other salticids have been investigated for their biocontrol potential, the two spider species previously suggested have not received attention in this regard, so their pest suppressing capabilities are not as explicitly defined (Hoefler et al. 2006).

The general movement of spiders between drainage ditches and their neighboring croplands are evidenced further by the Bray-Curtis dissimilarity ratios between the four habitat types for each sampling period. In my Bray-Curtis dissimilarity analysis, spider assemblages in soybean fields were shown to become more similar to those in drainage ditches as the growing season progresses in terms of spider abundance and diversity. The increase in similarity between the drainage ditch and soybean spider assemblages as the soybean growing season progresses is lends further evidence to the notion that spiders outside of soybean fields are colonizing those fields once the soybeans are grown enough to provide sufficient resources for spiders.

In terms of what environmental conditions influence spider assemblages and spider colonization in the ecosystem of drainage ditches and their neighboring croplands, it appears than ground temperature and relative humidity can safely be dismissed as a driving force in these spider assemblages. While changes in temperature and humidity have previously evidence of being able to influence where spiders can live in an ecosystem, no significant differences exist between the drainage ditches and their neighboring croplands sampled for these environmental conditions (Abraham 1983). Therefore, any effect on spider assemblages living in these habitats from ground temperature and humidity would only cause negligible differences between the drainage ditches and their neighboring croplands.

The plant assemblages present in drainage ditches likely influence what the spider assemblages look like in drainage ditches by dictating the prey abundance found in drainage ditches. As the plant assemblages in drainage ditches decrease in taxa richness and evenness as the growing season progresses, prey abundance in drainage ditch habitat types also decreases. Decreases in plant diversity such as these have previously been associated with less arthropod diversity and abundance in other agricultural systems (Landis et al. 2005). Furthermore, the linear regression analysis of prey abundance and spider abundance calculated a significant, positive association between the two variables. As a result, areas in drainage ditches and croplands with higher prey abundance coincide with higher spider abundances in those habitats. However, a linear regression analysis of the mean prey abundance in drainage ditches and the plant Shannon diversity of the ditch plant assemblages found a significant, negative association between the two variables. As plant Shannon diversity in drainage ditches already decline as the soybean growing season progresses, prey abundance in drainage ditches declines as well. As a result, drainage ditch habitat types experience a decrease in prey abundance as the soybean growing season progresses, while prey abundance in cropland habitat types increases as the soybean growing season progressed. Therefore, these changes in prey abundance in drainage ditches, which are brought on by the simplification of the ditch plant assemblages, are likely the cause of spider colonization of soybean fields from drainage ditches as the spiders seek out new prey resources present in the soybean fields. In other nonagricultural ecosystems, changes in plant diversity and prey abundance have also been shown to be indicators of what diversity and abundance of spiders will be found in those ecosystems (Halaj et al. 1998).

Overall, the spider assemblages present in drainage ditches likely account for a large portion of the spider assemblages present in soybean fields later in the growing season. Of the factors influencing the spider assemblages in drainage ditches, plant diversity indirectly influences spider abundance by dictating the prey abundance for spiders living in drainage ditches. Prey abundance directly influences spider abundances in drainage ditches and their colonization of croplands, as increased prey abundance significantly correlates to increased spider abundance. Two of the most common spider species collected from drainage ditches (*Zygoballus rufipes* and *Siticus concolor*) have been shown to colonize neighboring croplands as new survival resources become available, and as a result, are valuable as natural enemies in the croplands they colonize. My findings clearly depict that drainage ditches support prey populations for spiders during times when adjacent soybean fields are prey sparse. The spiders surviving on drainage ditches prey populations then move to soybean fields as the growing season progresses and new prey resources become available, which increases pest predation by spiders in soybean fields. As a result of these findings, drainage ditches provide value as sources of beneficial spiders for adjacent croplands, thus serving to enhance conservation biological control.

Literature Cited

Abraham, B. J. 1983. Spatial and temporal patterns in a sagebrush steppe spider community (Arachnida, Araneae). Journal of Arachnology, 11:31-50.

Aitchison, C. W. 1987. Feeding ecology of winter-active spiders. In Ecophysiology of Spiders (pp. 264-273). Springer, Berlin, Heidelberg.

Baba, Y. G., and Tanaka, K. 2016. Factors affecting abundance and species composition of generalist predators (*Tetragnatha* spiders) in agricultural ditches adjacent to rice paddy fields. Biological Control, 103:147-153.

Beltramo, J., Bertolaccini, I., and González, A. 2006. Spiders of soybean crops in Santa Fe province, Argentina: influence of surrounding spontaneous vegetation on lot colonization. Brazilian Journal of Biology, 66:891-898.

Blake, R. J., Woodcock, B. A., Westbury, D. B., Sutton, P., and Potts, S. G. 2013. Novel management to enhance spider biodiversity in existing grass buffer strips. Agricultural and Forest Entomology, 15:77-85.

Bommarco, R., Kleijn, D., and Potts, S. G. 2013. Ecological intensification: harnessing ecosystem services for food security. Trends in Ecology & Evolution, 28:230-238.

Breene, R. G., Sterling, W. L., and Nyffeler, M. 1990. Efficacy of spider and ant predators on the cotton fleahopper [Hemiptera: Miridae]. Entomophaga, 35:393-401.

Carter, P. E., and Rypstra, A. L. 1995. Top-Down Effects in Soybean Agroecosystems: Spider Density Affects Herbivore Damage. Oikos, 72: 433–439.

Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. Northwest Science, 33:39-64.

Duffey, E. R. I. C. 1966. Spider ecology and habitat structure. Senckenbergiana Biologica, 47:45-49.

Ferguson, H. J., McPherson, R. M., and Allen, W. A. 1984. Ground-and foliage-dwelling spiders in four soybean cropping systems. Environmental Entomology, 13: 975-980.

Gaba, S., Bretagnolle, F., Rigaud, T., and Philippot, L. 2014. Managing biotic interactions for ecological intensification of agroecosystems. Frontiers in Ecology and Evolution, 2: 29.

Geertsema, W., Rossing, W. A., Landis, D. A., Bianchi, F. J., Van Rijn, P. C., Schaminée, J. H., and Van Der Werf, W. 2016. Actionable knowledge for ecological intensification of agriculture. Frontiers in Ecology and the Environment, 14: 209-216.

Gillespie, R. G. 1987. The mechanism of habitat selection in the long-jawed orb-weaving spider *Tetragnatha elongata* (Araneae, Tetragnathidae). Journal of Arachnology, 15:81-90.

Green, J. 1999. Sampling method and time determines composition of spider collections. Journal of Arachnology, 27:176-182.

Halaj, J., Cady, A. B., and Uetz, G. W. 2000. Modular habitat refugia enhance generalist predators and lower plant damage in soybeans. Environmental Entomology, 29: 383–393.

Halaj, J., Ross, D. W., and Moldenke, A. R. 1998. Habitat structure and prey availability as predictors of the abundance and community organization of spiders in western Oregon forest canopies. Journal of Arachnology, 26:203-220.

Herzon, I., and Helenius, J. 2008. Agricultural drainage ditches, their biological importance and functioning. Biological Conservation, 141:1171-1183.

Hoefler, C. D., Chen, A., and Jakob, E. M. 2006. The potential of a jumping spider, *Phidippus clarus,* as a biocontrol agent. Journal of Economic Entomology, 99: 432-436.

Jackson, R. R., and Pollard, S. D. 1996. Predatory behavior of jumping spiders. Annual Review of Entomology, 41: 287-308.

Landis, D. A., Menalled, F. D., Costamagna, A. C., and Wilkinson, T. K. 2005. Manipulating plant resources to enhance beneficial arthropods in agricultural landscapes. Weed Science, 53: 902-908.

LeSar, C. D., and Unzicker, J. D. 1978. Soybean spiders: species composition, population densities and vertical distribution. Illinois Natural History Survey, Biological Notes; no. 107.

Li, X., Liu, Y., Duan, M., Yu, Z., and Axmacher, J. C. 2018. Different response patterns of epigaeic spiders and carabid beetles to varying environmental conditions in fields and semi-natural habitats of an intensively cultivated agricultural landscape. Agriculture, Ecosystems & Environment, 264:54-62.

Luczak, J. 1966. The distribution of wandering spiders in different layers of the environment as a result of interspecies competition. Ekologia Polska—Seria A, 14:233-244.

MacLeod, A., Wratten, S. D., Sotherton, N. W., and Thomas, M. B. 2004. ‘Beetle banks’ as refuges for beneficial arthropods in farmland: long-term changes in predator communities and habitat. Agricultural and Forest Entomology, 6:147-154.

Mansour, F., Richman, D. B., and Whitcomb, W. H. 1983. Spider management in agroecosystems: Habitat manipulation. Environmental Management, 7:43–49.

Marc, P., Canard, A., and Ysne, F. 1999. Spiders (Araneae) useful for pest limitation and bioindication. In Invertebrate Biodiversity as Bioindicators of Sustainable Landscapes, 74:229-273.

Marshall, S. D., Pavuk, D. M., and Rypstra, A. L. 2002. A comparative study of phenology and daily activity patterns in the wolf spiders *Pardosa milvina* and *Hogna helluo* in soybean agroecosystems in southwestern Ohio (Araneae, Lycosidae). The Journal of Arachnology, 30:503-510.

Mcnett, B. J. and Rypstra, A. L. 2000. Habitat selection in a large orb-weaving spider: vegetational complexity determines site selection and distribution. Ecological Entomology, 25:423-432.

Merrett, P., and Snazell, R. 1983. A comparison of pitfall trapping and vacuum sampling for assessing spider faunas on heathland at Ashdown Forest, south-east England. Bulletin of the British Arachnological Society, 6:1-13.

Needelman, B. A., Kleinman, P. J., Strock, J. S., and Allen, A. L. 2007. Improved management of agricultural drainage ditches for water quality protection: an overview. Journal of Soil and Water Conservation, 62: 171-178.

Nyffeler, M., and Benz, G.1987. Spiders in natural pest control: A review. Journal of Applied Entomology. 103: 321–339.

Nyffeler, M., and Birkhofer, K. 2017. An estimated 400–800 million tons of prey are annually killed by the global spider community. The Science of Nature, 104:30.

Nyffeler, M., Dean, D. A., and Sterling, W. L. 1987. Evaluation of the importance of the striped lynx spider, *Oxyopes salticus* (Araneae: Oxyopidae), as a predator in Texas cotton. Environmental Entomology, 16:1114-1123.

Nyffeler, M., Sterling, W. L., and Dean, D. A. 1994. How spiders make a living. Environmental entomology, 23:1357-1367.

Oberg, S., B. Ekbom, and R. Bommarco. 2007. Influence of habitat type and surrounding landscape on spider diversity in Swedish agroecosystems. Agriculture, Ecosystems & Environment. 122: 211–219.

Rand, T. A. 2017. Assessing the role of generalist predators in the biological control of alfalfa weevil (Coleoptera: Curculionidae). The Canadian Entomologist, 149:525-533.

Riechert, S. E. 1985. Decisions in multiple goal contexts: habitat selection of the spider, *Agelenopsis aperta* (Gertsch). Zeitschrift für Tierpsychologie, 70: 53-69.

Riechert, S. E., and Bishop, L. 1990. Prey control by an assemblage of generalist predators: Spiders in garden test systems. Ecology. 71:1441–1450.

Riechert, S. E., and Lockley, T. 1984. Spiders as biological control agents. Annual Review of Entomology, 29: 299-320.

Royall, R. M. 1986. The effect of sample size on the meaning of significance tests. The American Statistician, 40: 313-315.

Samu, F., Sunderland, K. D., and Szinetar, C. 1999. Scale-dependent dispersal and distribution patterns of spiders in agricultural systems: a review. Journal of Arachnology, 27:325-332.

Sandhu, H. S., Wratten, S. D., and Cullen, R. 2010. Organic agriculture and ecosystem services. Environmental Science & Policy, 13:1-7.

SAS Institute Inc. 2019. SAS University Edition 3.8 Interface. Cary, NC.

Scheidler, M. A. 1990. Influence of habitat structure and vegetation architecture on spiders. Zoologischer Anzeiger, 225: 333-340.

Schmidt, M. H., Roschewitz, I., Thies, C., and Tscharntke, T. 2005. Differential effects of landscape and management on diversity and density of ground-dwelling farmland spiders. Journal of Applied Ecology, 42, 281-287.

Swinton, S. M., Lupi, F., Robertson, G. P., and Hamilton, S. K. 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. Ecological Economics, 64:245-252.

Symondson, W. O. C., Sunderland, K. D., and Greenstone, M. H. 2002. Can generalist predators be effective biocontrol agents? Annual Review of Entomology, 47: 561-594.

Toft, S. 1987. Microhabitat identity of two species of sheet-web spiders: field experimental demonstration. Oecologia, 72: 216-220.

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., .and Whitbread, A. 2012. Global food security, biodiversity conservation and the future of agricultural intensification. Biological conservation, 151: 53-59.

Ubick, D., Paquin, P., and Cushing, P. E. 2017. Spiders of North America: an identification manual. American Arachnological Society.

Uetz, G. W., Halaj, J., and Cady, A. B. 1999. Guild structure of spiders in major crops. Journal of Arachnology, 27:270-280.

Uetz, G. W., Johnson, A. D., and Schemske, D. W. 1978. Web placement, web structure, and prey capture in orb-weaving spiders. Bulletin of the British Arachnology Society, 4: 141-148.

Winemiller, K. O., Flecker, A. S., and Hoeinghaus, D. J. 2010. Patch dynamics and environmental heterogeneity in lotic ecosystems. Journal of the North American Benthological Society, 29:84-99.

World Spider Catalog 2020. World Spider Catalog. Version 21.0. Natural History Museum Bern, online at http://wsc.nmbe.ch.

Young, O. P., and Lockley, T. C. 1985. The striped lynx spider, *Oxyopes salticus* [Araneae: Oxyopidae], in agroecosystems. Entomophaga, 30:329-346.

Ziesche, T. M., and Roth, M. 2008. Influence of environmental parameters on small-scale distribution of soil-dwelling spiders in forests: What makes the difference, tree species or microhabitat? Forest Ecology and Management, 255: 738-752.