THE CORN FIELD SPIDER COMMUNITY:
COMPOSITION, STRUCTURE, DEVELOPMENT AND FUNCTION

By

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Dedicated to my Parents

Joseph R. Plagens

and

Frances L. Plagens

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By

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An agroecosystem approach was taken in analyzing the
the spider communities in Alachua County, Florida,
cornfields.

Visual examination of the corn plants detected 140
species and details of 40 species' microhabitat, prey and
reproduction. The most common were Pardosa milvina,
Achaearanea globosa, Misumenops celer, Tetragnatha
laboriosa, Eperigone banksi, Metaphidippus galathea and
Uloborus glomosus.

Community structure and stratification are presented.
Guild dynamics was similar between fields and years.
Maximum species diversity was 61 species and $H' = 4.08$. The
density of spiders ranged from 2.2 - 9.5/m².

Prey is recorded for 29 spider species. Solenopsis ants are major prey of Achaearanea globosa and Eperigone banksi. Parasitic hymenoptera are major prey for Araneidae. Insects feeding on the copious pollen are chief prey for spiders and divert predation away from major pests.

Aerial dispersal of spiders in the ecosystem was studied using sticky wires which trap mostly spiders. The seasonal phenology of the 15 families and 53 species trapped revealed five dispersal strategies; spiders with widely overlapping generations and several instars ballooning throughout the year are dominant components of the aeronaut, crop field, and weed faunas.

The principal spiders and their seasonal phenology on the weeds of the ecosystem are presented. Most major species are shared with crop fields and frequent movement between plant species is characteristic. Oak trees in fence rows are a major source of crop and weed spiders.

The overwintering ecology of spiders and predaceous insects in the cornfield was examined; 24 species of spiders and 25 predaceous insects were found in the cavities formed by the leaf sheath and/or the imbricate bracts of the shelled corn cob.

The determinates of crop field spider communities are divided into those which affect the diversity of the pool of dispersing colonists and the biological and ecological factors which favor or exclude species which arrive in the

field. Cornfields are a tremendous sources of spiders, parasitoids, and pests, and because corn is a major worldwide crop, management of the agroecosystem and thus the spider communities in cornfields is essential.

CHAPTER I INTRODUCTION

Since the resurgence of research in biological control in the early 1960's, and the pioneering work of Whitcomb, Exline and Hunter (1963) the volume of literature on spiders in crop fields has steadily increased. Luczac (1979) and Riechert and Lockley (1984) provide useful reviews of this material.

Most of the published studies list the species found and their relative abundance on a particular crop in a particular area, such as on cotton in Arkansas (Whitcomb et al. 1963), Texas (Kagan 1943, Dean et al. 1982), California (Leigh and Hunter 1969) and in Peru (Aguilar 1968); on alfalfa in New York (Wheeler 1973), Virginia (Howell and Pienkowski 1971) and California (Yeargan and Dondale 1974).

A few studies consider the seasonal dynamics of a single spider (Plagens 1983) or groups of spiders (Lockley et al. 1979). Culin and Yeargan (1983a,b) in a unique way consider the dynamics and compare the spider communities found in soybean versus alfalfa. A central theme of Luczac's (1979) paper was a contrast of the communities occurring in different crops. Riechert and Lockley (1984)

focused on a theme concerned primarily with potential predator/prey relationships and their impact upon the effectiveness of spiders as biological control agents.

However, the spider fauna of many of our most important crops, particularly row crops, have yet to be considered. In addition, basic questions concerning the mechanisms that structure the communities and the potential for spiders to affect control of pests or potential pests have received scant attention. That habitat structure, microclimate, habitat stability, prey availability and diversity can all influence the composition and dynamics of a spider community is generally accepted. But the relative importance of these factors and their interactions are highly debatable given the complexity of the systems and the dearth of information.

The following report explores as many aspects of the spider community in a major crop, field corn, with the intent of discerning the mechanisms which produce the observed community structure. This knowledge is vital if we are to manipulate the predator complexes of crop fields to our benefit.

CHAPTER II
THE SPIDER FAUNA
OF CORN FIELDS IN ALACHUA COUNTY, FLORIDA

Introduction

Corn, Zea mays, is grown on some 30×10^6 hectares in the United States and 163×10^6 ha. world wide (Corn Refiners Assoc. 1982). Yet little information has been published on the predaceous arthropods found in this major crop. This is surprising, especially since pest management in corn is so dependent on naturally occurring biological control because of its low cash value and its importance in underdeveloped areas of the world. Everley (1938a, 1938b, 1939a, 1939b, 1940) in a series of papers listed the arthropods, including the spiders, that he had collected in a rather casual manner from a small field of sweet corn in Ohio. Dritschilo and Erwin (1982) studied the effect of cultivation techniques on the abundance and diversity of carabidae in an Iowa corn field, while Isenhour and Yeargan (1981) studied the phenology of Orius in field corn.

Luczac (1975, 1979) in her extensive research into the spiders of crop fields mentioned the spiders of maize in Poland, but this crop was a minor component in her study. Work on spiders in similar crops includes that of Baily and Chada (1968) in Oklahoma who conducted a thorough study of spiders occurring in sorghum which is botanically related to corn. A few studies of spiders occurring in cereal crops have been conducted in Canada (Doane and Dondale 1979, Fox and Dondale 1972) and Europe (Nyffeler 1982, Luczac 1979).

Altieri (1979) has made major contributions to the understanding of how diversifying cropping systems can influence the diversity and abundance of the natural enemies. In field corn, he has shown that predaceous arthropods were more abundant in plots intercropped with selected weeds than in plots kept free of weeds. In addition, levels of infestation by Spodoptera frugiperda were lower in the weedy plots than in the weed free plots.

In Florida, corn is grown on approximately 130,000 hectares mostly in relatively small fields of 20 to 100 hectares (Komarek 1951). Most of the state's production is concentrated in the panhandle region. A large percentage of the crop is kept by the grower as feed for his own livestock and is an integrated part of a farming system which normally includes other summer crops such as sorghum, peanuts, tobacco, watermelons or soybeans, as well as livestock. Many fields are double cropped with rye, winter wheat or winter

vegetables. And because we cannot consider a crop field to be a closed system, but rather part of the total agroecosystem, we must consider the role of the corn field both as a source and as a sink for both pests and beneficial insects.

The first step in understanding the role that spiders play in the corn field ecosystem, as in any crop (Whitcomb 1980, Dean et al. 1982) is to determine the composition of the community. In addition to this central goal, I hoped to help answer several basic questions concerning the ecology of crop spider communities:

(1) How are the various species distributed upon the corn plant? Whitcomb et al. (1963) and LeSar and Unzicker (1978) showed clearly that different strata in the crop canopy are inhabited by different species. Do these stratifications relate to structural constraints, microclimate, location of prey or a combination of these?

(2) How are the spiders distributed within the field? That is, are there significant border effects on the density and diversity of the spider community? Are some species regularly or gregariously distributed in the field rather than randomly? Pieters and Sterling (1974) found that spiders were the least aggregated of the predaceous arthropods in a Texas cotton field, while Bishop (1981) found just the opposite in Australian cotton. Altieri and Todd (1981) found that predaceous arthropods were more abundant in

soybean rows adjacent to weedy borders than in the field center.

(3) By direct observation of predation in the corn field, what species or classes of prey are taken by the different spiders?

(4) How do the structure and size of the spider community change during the season and how is this related to the phenology of the corn crop?

(5) How does the nature of the surrounding vegetation and land management influence the structure and development of the spider community? Is there consistency in the structure of the spider communities from season to season even in the same general area? Culin and Yeargan (1983a, 1983b) found that the more perennially stable alfalfa tended towards a more similar community structure from year to year than did an adjacent soybean field which apparently started with a new set of spider colonists of slightly different species composition each year. They also suggested that the nearby alfalfa field was contributing to the annual flux of spiders into the new crop field. Dondale et al. (1979) found consistency in the spider faunas of apple orchards through the northeast United States and Canada.

(6) Which spiders in the corn field actually reproduce there? LeSar and Unzicker (1978) stated that few if any spiders can reproduce in Illinois soybean fields.

(7) And, finally, what factors, both biotic and abiotic, tend to limit or benefit the populations of spider species and/or the community as a whole? Specifically, are predation on spiders or competition with other predaceous arthropods of importance in regulating spider populations?

Site Descriptions

A total of six corn fields were intensively studied during the period of April 1982 through July 1984. Four of these fields were located within a mile of each other near Archer, situated in southwestern Alachua County. A fifth field was located near Orange Heights at the eastern edge of the county. The sixth field, just northwest of Gainesville, was located near the county center. In the selection of the fields, every effort was made to include the widest possible range of adjacent habitats.

The Archer fields were part of the same farmers' operation where peanuts, watermelons, forage grasses and cattle pasture were rotated with corn. The soil was a deep, well drained and leached Candler Fine Sand (USDA 1980). Although the nearby uncultivated habitat was primarily xeric hammock of Quercus virginiana/Q. laurifolia (Live Oak/Laurel oak), many years of cultivation had oxidized the organic matter in the crop fields so that a sandhill habitat was resembled. Burrows of the gopher tortoise were found in the fields, a

resident typical of sandhills in Florida. True sandhill scrub of Quercus laevis (Turkey Oak)/ Pinus clausa (Sand Pine) grow naturally within 8 kilometers of these fields. Sprinkler irrigation is necessary, and during the hottest, driest periods the pumps run continuously to keep the corn adequately watered. Two adjacent fields were sampled during 1982 (AR82-A and AR82-B), and one each during 1983 (AR83), and 1984 (AR84).

Field AR82-A had on its east border a fence row of trees (Quercus spp. and Celtis laevigata) beyond which was a 50 ha. fallow field which was periodically grazed by cattle. The vegetation was composed primarily of herbaceous plants that cattle avoid grazing: Sida rhombifolia, Chenopodium ambrosioides, Ambrosia artemisiifolia, Oenothera sp. and Cassia spp. The north border had a 15 ha. enclosure where hogs were kept; here there were patches of bare soil and large areas of tall Amaranthus, Chenopodium, and Sida rhombifolia. To the west and south were borders of trees (again Quercus and Celtis) which divided the field from adjacent corn fields.

This corn field to the south was AR82-B. The areas east, south and west of this field were improved cattle pastures of Bahia Grass (Paspalum notatum). The only weeds in these pastures were scattered clumps of Asimina spp. (Paw-Paw). The field to the east also contained a

residence, and a border of trees. In addition, the field also had two large laurel oaks growing within it, under which were a variety of weeds, similar in species composition to the weeds growing under the tree borders. These were seedlings of trees such as Celtis and Quercus, and herbs such as Ambrosia artemisiifolia, Callicarpa americana, Solanum americana and Phytolacca americana.

In 1983 and 1984 the Archer fields were again very dry and sandy, but the vegetation and adjacent habitat supported different plant communities due to varying management and use. The layout of AR83 was a large (50 ha.) continuous field of corn; sampling was concentrated in the southwestern corner of the field. Along the south border of the field was a band, 20 meters in width, which supported a diverse community of herbaceous and woody weeds. The most abundant of these are listed in Table 2-1. Beyond this was an overgrazed horse pasture which was heavily infested with Eupatorium and Asimina. To the west was a border of large oak trees and then a plantation of slash pine with a dense understory of oak saplings. Several mature slash pines were left standing within the corn field and were surrounded by weed patches of Rubus and Ambrosia. The area north of the field consisted of dense herbaceous weeds (Desmodium, Indigofera, Cassia) surrounding a cattle pond. Beyond the east end of the field was improved Bahia Grass pasture.

The 1984 Archer corn field (AR84) had a weedy (Rubus and Asimina) bahia grass pasture to the south, a plantation

Table 2-1. Weeds growing in the south border of the Archer, Florida corn field during May of 1983.

ASTERACEAE	
<u>Heterotheca subaxillaris</u>	<u>Lactuca graminifolia</u>
<u>Eupatorium capillifolium</u>	<u>Ambrosia artemisiifolia</u>
<u>Gnaphalium obtusifolium</u>	<u>Hieracium gronovii</u>
ONAGRACEAE	ROSACEAE
<u>Gaura angustifolia</u>	<u>Rubus</u> sp.
POLYGONACEAE	FABACEAE
<u>Rumex</u> sp.	<u>Arachis hypogaea</u>
PHYTOLACCACEAE	BRASSICACEAE
<u>Phytolacca americana</u>	<u>Lepidium virginicum</u>
MALVACEAE	POLEMONIACEAE
<u>Sida rhombifolia</u>	<u>Phlox drummondii</u>
SOLANACEAE	AMARANTHACEAE
<u>Solanum americanum</u>	<u>Amaranthus hybridus</u>
RUBIACEAE	SCROPHULARIACEAE
<u>Richardia scabra</u>	<u>Linaria canadensis</u>
APIACEAE	CYPERACEAE
<u>Ptilimnium capillaceum</u>	<u>Cyperus</u> sp.
	CAPRIFOLIACEAE
<u>Triodanis perfolia</u>	<u>Wahlenbergia marginata</u>
	VITACEAE
<u>Vitis tomentosa</u>	<u>Parthenocissus quinquefolia</u>

of slash pine with dense oak undergrowth to the southwest and north, peanuts planted in May to the west, a wide border of xeric hammock (Quercus spp.) to the northeast and a several hectare field of weeds on the southeast. This field was also quite large (60 ha.) and sampling was concentrated in the south end.

The field sampled in 1983, located near Orange Heights, presented a radically different habitat. The soil, classified as a Mulat Sand, was water logged for extended periods and so a considerable quantity of black organic muck was incorporated with the sand. Portions of the field were too wet for farm equipment to be operated and planting was delayed until April due to flooding. A pond at the center of the field contained the remnants of a cypress dome: Taxodium distichum (Pond Cypress), Nyssa aquatica (Tupelo) and sedges. Completely surrounding the 40 ha. field were slash pine plantations with an understory of Myrica cerifera (Wax Myrtle) and Ilex glabra (Gall Berry). Cattle were allowed to graze the rich flora of grasses and herbs underneath. This herbaceous flora included Eryngium prostratum, Hypericum spp., Lobelia nuttallii, Polygala incarnata, Xyris spp., Rhexia mariana and Sarracenia sp. Field corn was rotated with soybeans, and vegetables such as cabbage, pole beans, strawberries and sweet corn.

The last field, Gainesville 1984 (GN84), about 30 ha. in size, was cut from terrain that had supported the diverse

southern mixed hardwood forest (Monk 1965) on Norfolk Loamy Fine Sand. Relatively undisturbed sections of this vegetation type were located to the west, southeast, and east of the field. Paved highways separated the field on the north from a 15 ha. fallow field, and from the forest on the east. The borders around the field were mostly quite wide (10 to 20m) and had scattered trees such as Pinus taeda (loblolly pine), Quercus laurifolia, Q. nigra (water oak), Prunus serotina (black cherry), Liquidambar styraciflua (sweet gum), Myrica cerifera and Prunus angustifolia (Chicksaw Plum). Beneath these trees grew thickets of shrubs and tall herbs, especially Rubus, Desmodium and saplings of trees. Beyond the border on the southwest was another corn field of 20ha.

Sampling Methods

A sample, as defined in this study, consisted of a set of continuous corn plants in one planted row. During the 1982 season this consisted of either 5 or 9 plants, while all samples included 10 plants in 1983 and 1984. Spiders were collected from the sample unit by careful visual examination. First, the fast running Pardosa wolf spiders were noted, and, if their identification was not certain, they were captured in individually numbered snap cap vials for later identification. Next, the soil was examined closely for the delicate webs of Linyphiidae and Hahniidae

whose webs were often made visible by droplets of dew (Whitcomb 1980) or pollen dust. These small, easily damaged spiders were collected by aspirator. A small hand trowel was used to uncover soil dwelling hunters from their burrows in the soil.

The base of the corn plant warranted close attention. Many spiders find a niche among the prop roots and lowest leaves. Tapping of the leaves with a pencil was used to dislodge spiders from the lower surface and pulling the leaves away from the stem frequently revealed the hiding spot for cursorial species. Moving up the plant, each leaf was examined on the upper and lower surfaces. The corn silk required special attention because spiders of at least three families constructed their silken retreats deep within the strands. The tassel was also examined closely after which it was given a stiff rap that occasionally dislodged undetected spiders. Once this systematic inspection was completed for each plant, the plants were shaken vigorously and dropping spiders were collected; the efficiency of the visual examination was confirmed by only infrequently catching spiders by this final method.

This sampling method allowed me to record for each specimen, the precise location on the plant or soil that was inhabited. It also allowed for many prey records and specific interactions to be observed. To accomplish this, careful notes were taken and each specimen was numbered and

preserved separately until its specific determination was certain. For juvenile specimens, identification was not accomplished until I became familiar with the fauna and could match them with their adult counter parts.

Sample sites within the fields were selected by making a transect through the field from one of the borders. The starting point was usually not more than ten rows from the field edge, and each additional site was reached by moving a given number of rows (consistent for any sampling date, and between 10 and 30). This sampling scheme allowed me to analyze the "border effect" on spider density and diversity. The number of samples that could be taken on a given day was largely a function of the size of the plants and the density of spiders. Early in the season, as many as 20 sets of ten corn plants could be examined as described above, whereas at maturity, only three sets could be completed during the sampling period, from 0730 hrs to 1130 hrs. For analysis, the seasons' samples for each field were divided into three periods based on the phenology of the corn plants: Growth, Flowering, and Mature.

Identification of spiders was accomplished through the use of family and generic keys (Kaston 1978, 1981), the numerous published specific keys (listed separately under each family) and by comparison with specimens in the well curated Florida State Collection of Arthropods (FSCA). Dr. G. B. Edwards, of the FSCA, verified the majority of the

identifications, while spiders of the family Linyphiidae were identified by Dr. Charles Dondale of Agriculture Canada. Voucher specimens of all collected species are deposited in the FSCA. As mentioned above, juvenile spiders could, for the most part, be determined by comparing them to series of specimens from the same locality that included adults. Obtaining such series usually required collection of specimens before or following the crop period on nearby weedy vegetation (Whitcomb 1980). Nevertheless, for some closely related species that occurred together in the same area, reliable identification beyond the generic level was not possible, especially for very small specimens.

Results

Checklist and Description of the Species

The spiders collected in the corn field are here listed by family. After a general discussion of the each family, the species found are listed with their authors. Species marked with two asterisks constituted at least 5% of the spiders collected, in at least one of the six fields, during at least one of the sampling periods. Those which made up more than 1% are marked with one asterisk. Those species which are marked with an asterisk or those which are of particular interest are discussed separately.

Uloboridae. These spiders, like those discussed under the next family, use a variety of silk which is much different than that of other spiders (Foelix 1982). The silk adheres to the cuticle of insect prey by virtue of its finely hackled threads which act like Velcro to ensnare tiny projections and setae on the insect. This is in contrast to the adhesive glue found on the sticky webs of other spiders. The family was revised by Muma and Gertsch (1964). Two species of this small family of spiders were found:

*Uloborus glomosus (Walckenaer)

Uloborus sp.

Uloborus glomosus builds a horizontal or tilted orb web that has a bluish-grey cast due to the hackled silk. It appeared in the field only after the canopy was well developed and then in the lower third of the canopy. Very small juveniles as well as adult females and males were collected. These spiders were common at all three sites but were never abundant.

Dictynidae. Although this is a large and diverse group of rather small spiders (Chamberlin and Gertsch 1958), only three specimens, representing two, as yet, unidentified species were encountered:

Dictynidae:

Dictyna sp. ADictyna sp. B

Theridiidae. The comb-footed spiders, a large and diverse group of spiders, were well represented in the corn field by 15 species and 250 specimens. These spiders build irregular space webs of strong, sticky silk that are especially designed to capture crawling insects. Figure 2-1 shows the vertical stratification and usual web placement for the common species. Many of the generic keys have been published by Levi (1955, 1957, 1963) and Levi and Levi (1962). Exline and Levi published the revision of Argyrodes (1962). The specimens collected were identified as

Achaeearanea near rupicola (Emerton)**Achaeearanea globosa (Hentz)Anelosimus studiosus (Hentz)Argyrodes fictilium (Hentz)Argyrodes sp. AArgyrodes sp. B*Coleosoma acutiventer (Keyserling)*Latrodectus mactans (Fabricius)Steotoda quadrimaculataSteotoda erigoniformis

Theridion albidum Banks

Theridion crispulum Simon

**Theridion flavonotatum Becker

Theridion pictipes Keyserling

*Theridula opulenta (Walckenaer)

Tidarren sp.

Achaearanea globosa was one of the most characteristic spiders of corn fields in Alachua County. It was common in the 1983 Archer field, nearly absent from the 1982-A Archer field and abundant in the remaining fields. A. globosa made up 16% of the spiders collected during the flowering period at the Gainesville field. This is a small spider, usually less than 1.5mm in length as an adult female, but it is easily recognized by the conspicuous black spot on the dorsal surface of the abdomen.

A. globosa's web was nearly always in close proximity to the ground (see Figure 2-4) and close to the stem of the plant. As shown in Figure 2-1 it is placed either in the leaf axil, or on the lower surface of a leaf near the base and stretching down to the next lower leaf or to the soil. The principal prey, as recorded many times during the study, were ants, particularly Solenopsis spp. It reproduced freely in the field. The index of dispersion (Southwood 1978) for this spider increased during the flowering and mature periods, reflecting the pockets of offspring and the

Figure 2-1. Distribution and typical web structures of spiders occurring on the corn plant. Theridiidae: 1. Ach-aeranea globosa, 2. Coleosoma acutiventer, 3. Latrodectus mactans, 4. Theridion flavonotatum, 5. Theridula opulenta. Linyphiidae: 6. Eperigone banksi, 7. Frontinella pyramitela, 8. Ceraticelus similis.

rarity with which it disperses by air (see Chapter III). Prey of the young A. globosa consisted of the plentiful psocoptera and collembola that multiply on the shed pollen and dying corn leaves.

On several occasions I found series of empty A. globosa webs and later found a Mimetus spider nearby feeding on yet another spider in its web. Achaearanea spp. are frequent prey as well in the nests of Scelephron (Hymenoptera: Sphecidae, Rau 1935).

Anelosimus studiosus is one of the most curious spiders in Florida by virtue of its sociality (Comstock, 1948). Rather than leaving the maternal web, offspring remain to help enlarge the web and subdue larger prey. Two such colonies were found in the corn fields at Archer. The colony found in 1982 contained only a female and a dozen of her offspring, but the web found in 1983 covered the entire plant and contained an estimated 100 spiders. Most of these were small juveniles. The corn plant itself had turned brown, presumably due to the light-blocking web.

Argyrodes fictilium was only rarely encountered in the corn fields, but was in two instances taken while it fed upon another spider. Argyrodes spp. are believed to be primarily kleptoparasitic (Exline and Levi 1962); that is they live in the webs of larger spiders and feed unnoticed on the larger spider's prey. Trail (1980), however, also recorded A. fictilium as predatory in nature. The four

specimens that I collected were mature males and females that might well have taken many spiders as prey before my capturing them. In addition, I found a juvenile of another species of Argyrodes preying upon Grammonota texana, a small linyphiid spider. This suggests that the predatory behavior of Argyrodes spp. may be more widespread than previously recognized.

Coleosoma acutiventer is a bit larger than Achaearanea globosa, and coal black in color with an elongate, oddly shaped abdomen. It, too, was found preying on Solenopsis ants and constructed its web close to the ground and the plant stem, often in the axil of a leaf which had fallen away from the corn plant. It was collected at Archer and Orange Heights, but was common only at the Gainesville field. Adult females protecting egg sacs and newly hatched young were found at the Gainesville and Archer fields. As a very curious observation, an adult male C. acutiventer was found clutching a batch of eggs, yet no female specimens were detected in the vicinity.

Latrodectus mactans, the black widow spider, was most common at the Archer fields. No mature specimens of this species were found in the corn field, although rather large juveniles up to 10mm in length were collected just before the crop was harvested. As its name suggests, this spider is jet black, while its globular abdomen is variously marked with red and/or yellow on the ventral surface. The silk is

very strong and studded with droplets of glue. When small, the webs of this spider resemble A. globosa's but as the spiders grow larger, they climb higher and higher up the plant constructing a large web that extends to the soil surface. As described in Kaston (1970), the vertical strands of silk that attach to the ground are ideally suited for the capture of strong crawling insects such as beetles and ants. I recorded Solenopsis spp. as prey for Latrodectus mactans in the corn field. In the borders of the Archer fields were piles of old lumber and boulders among which there were numerous L. mactans including egg producing females. These are the refugia and nurseries for the black widow spiders that colonize the field.

Theridion flavonotatum was the only member of its genus that was commonly encountered, and then only at the Gainesville field where it comprised 5% of the spider community when the crop was mature. Its irregular space web is constructed on the undersurface of middle canopy leaves. Unlike the web of Theridula opulenta (discussed below), guy lines do not extend down to the next leaf. As prey, I recorded Cicadelidae, Aphidae, Ottitidae (leaf mining diptera), and small parasitic hymenoptera. I found adult, reproducing females on the corn plants by the time the corn plants reached maturity.

During the study, I collected only six other specimens of Theridion spp. Two of these, however, were with eggs

and/or young spiders in the web. Both of these species, Theridion pictipes and T. albidum, are larger than T. flavonotatum. Their irregular webs included as many as 3 corn leaves. A Theridion pictipes web was found with a half dozen mummies of already consumed Solenopsis invicta, but was itself being consumed by a pirate spider, Mimetus.

Theridula opulenta is an easily recognized spider with its transversely oblong abdomen marked with two or four yellow spots. The web of the adult spiders can vary in structure, but in the corn fields of Alachua Co. the structure shown in Figure 2-1 predominated. The irregular top portion captures insects that fly or crawl into the under surface of the leaves. Additional strands of tough silk are also attached to the next lower leaf. Here they can intercept insects that walk over the surface of the leaf below. The prey of these spiders, as recorded in this study, are similar to that of Theridion flavonotatum but also include ants as prey. Although present at all six fields, T. opulenta was common only at the Gainesville field.

Linyphiidae. In many ways the Linyphiidae were the most difficult family of spiders to deal with. Their size is generally minute, with adults often measuring just a millimeter in length. The webs too, are tiny, delicate and inconspicuous. Countless species, many of which are poorly, if at all, described in the literature are nearly impossible

for the uninitiated to identify. Many of the most important genera have not been revised since the works of Bishop and Crosby (1932) and Crosby and Bishop (1928, 1933). The juveniles especially, are difficult to identify with any degree of certainty, and many of the tiniest specimens in the samples were surely overlooked.

Except for a few species (see Figures 2-1 and 2-3), these spiders were closely associated with the soil and/or the base of the corn plant, where moisture is higher and their prey of collembola, psocoptera, and nematocerans are concentrated. The abundance and diversity of linyphiidae varied greatly between the six fields, apparently as a function of the moisture level in the soil. These spiders are avid ballooners (Glick 1939, Duffy 1956, Dean and Sterling 1985 and see Chap III) and have been treated as a distinct ecological group by researchers (e.g. Luczac 1979) in crop spider ecology because they frequently arrive in the fields as adults which can begin reproducing immediately. Duffy reported that significant numbers of Linyphiidae can survive cultivation while Thornhill (1983) has published a comprehensive analysis of linyphiid in British sugar beet fields. The species I collected are as follows:

Anibontes longipes Chamberlin & Ivie

*Ceraticelus similis (Banks)

Ceraticelus sp. A

Ceratinops crenatus (Emerton)

Ceratinopsis sutoris

**Eperigone banksi Ivie & Barrows

Erigone autumnalis Emerton

*Florinda coccinea (Hentz)

*Frontinella pyramitela (Walckenaer)

*Grammonota texana (Banks)

Meioneta micaria (Emerton)

**Meioneta spp. (4 species)

**Tennesseelum formicum (Emerton)

Genus et species indet. (ca. 7 species)

Ceraticelus similis is one of four species of Linyphiidae that was most frequently taken from the foliage layer of the corn field. Its sheet web was constructed on the under surface of corn leaves, particularly ones that had curled and were in the lower third of the plant. The spiders are orange-red, with a nearly spherical abdomen, and measure 2mm or less at maturity. These spiders were encountered with regularity at all six corn fields surveyed.

Eperigone banksi accounted for 200 of the 2300 spiders collected from corn fields; only Pardosa milvina had a larger representation. Although E. banksi was found in all six fields, the greatest number of these were collected at the Orange Heights field. At Orange Heights these spiders were abundant even during the seedling and growth stages,

when they were aggregated in clumps of sod left partially turned by the cultivator. Eventually these spiders and/or there offspring spread out to colonize the whole field.

The web consists of a delicate sheet that employs tiny weed seedlings, clumps of soil, or the lowest leaves and prop roots of the corn plant as supports. This design is used by many of the linyphiid species occurring in crops (Thornhill 1983). E. banksi is up to 3mm in length as an adult, and moves about on the undersurface of the web. Prey that I observed being taken included collembola, psocoptera, diptera, Cicadelidae and not infrequently Solenopsis.

Florinda coccinea was the largest of the linyphiidae that I found in Alachua Co. corn fields, reaching 4mm in length. It is easily recognized by its bright red color and tubercled abdomen. It is a foliage level species, inhabiting the lower third of the plant where it constructs a sheet and lattice web that typically spans from the upper surface of the leaf base to the stem and usually to a leaf or stem of an adjacent plant. It was present in all six fields, but was commonest at the Orange Heights and Gainesville fields. No adult females were found in the corn field, with the majority of collections being early to middle instar juveniles. In adjacent habitat adults were found at most times of the year, including winter.

Frontinella pyramitela was a commonly collected spider at the AR82-B and Gainesville fields. It was also present

at the other fields. Most of the specimens were less than 3mm in length, none of which were adults. The common name of this spider is "The Bowl and Doily Spider" after a description of the web. It consists of a flat sheet of silk over which is constructed a loosely woven lattice of space webs. Small flying insects collide with these fine strands and fall upon the silken net below. The spider maneuvers on the underside of the web to the fallen prey and bites it through the sheet. Thus, as I have recorded here, the major prey are tiny diptera, hymenoptera, alate aphids and cicadellids. This construction is similar to that of F. cocci-nea's, but is situated higher in the plant at mid level.

Grammonota texana specimens were encountered at the base of the corn plant, but also with regular frequency in the canopy. When found on the plant itself, the web occupied the space created by the leaf axil or a curled leaf. The delicate sheet web did not have an overhead lattice. This spider was present at all six corn fields, but with greatest frequency at the Orange Heights and 1983 Archer fields where reproducing females were found. Predation by this species was not observed.

Meioneta spp., as a group, were collected in all six fields, being common at the Orange Heights, Gainesville and two of the Archer fields. However, they are difficult to differentiate at the species level, even when adult specimens are available. The webs of the five species are

similar, in that they were usually associated with the prop roots and/or the lowest leaves. A sheet web is combined with a course, overhead lattice composed of relatively strong threads. The adult males of this species roam on foot searching for females, and because they are very ant-like in form and behavior they may achieve a certain amount of protection.

Tennesseelum formicum was found with regularity at moderate levels at all six fields, but was most common at the AR82-A and Gainesville fields. Its web and the behavior of the males is quite similar to Meioneta's. Although I did not find any females with eggs, reproduction in the field likely occurred since adults of both sexes were found as well as patches of numerous juveniles.

Theridiosomatidae. This is a small family of minute spiders which are classified as members of the Araneidae by some authors (Levi 1980). The tiny orb web is built close to the ground in moist, protected situations. Its web differs from typical araneid webs (Kaston 1965) by having an indistinct hub; the radii meet at 3 or 4 points rather than a single center. Also, the spider sits not at the hub of its orb web, but rather at the end of a strand attached to the hub. All but one of the five specimens representing this family were found in the Orange Heights field. The single species was

Theridiosomatidae:

Theridiosoma radiosa (McCook)

Araneidae. No other family of spiders had more species or individuals than the Araneidae, the orb weavers. Twenty-six species were recorded from the six Alachua County corn fields. As would be expected, a wide range of size, morphology, behavior, habitat selection and web structure is found among this diverse fauna. Luczac (1975) also noted the strong representation of Araneidae in corn fields.

Three basic variations of web orientation and construction are used by the species found in the corn field. The first of these types has the plane of the orb web parallel to the ground. All of the species of this type that I found in the corn fields have webs made of light, flexible silk that yields to air currents, allowing the web to sway up and down. Craig et al. (in press) suggest that this is an adaptation for increasing the probability of capturing nematoceran flies. The second basic design has the plane perpendicular to the ground and constructed from relatively tough, inflexible silk. The spider sits at the hub of such a web during the day. The third design is also perpendicular to the ground, but has an additional component of a retreat in the upper corner of the web where the spider hides during the day. In some species that use this third

Figure 2-2. Stratification of the vertical plane orb webs, Araneidae: (Nocturnal) 1. Acanthepiera sp., 2. Eriophora ravilla, 3. Araneus pagnia, 4. Eustala anastera, 5. Neoscona arabesca, (Diurnal) 6. Gea heptagon, 7. Argiope trifasciata, 8. Cyclosa turbinata. Horizontal line: Mean. Vertical Box: Approximate Standard Deviation. Vertical Line: Range.

Figure 2-3. Stratification of the horizontal plane orb webs, Araneidae:
1. Leucauge venusta, 2. Tetragnatha laboriosa, 3. Mangora gibberosa, 4.
Mangora spiculata, and horizontal plane sheet webs, Linyphiidae: 5. Flor-
inda coccinea, 6. Frontinella pyramitela, 7. Ceraticellus similis, and 8.
Grammonota texana. Horizontal line: Mean. Vertical Box: Approximate
Standard Deviation. Vertical Line: Range.

Figure 2-4. Stratification of the tangled space webs, Theridiidae: 1. Steotoda spp., 2. Latrodectus mactans, 3. Coleosoma acutiventer, 4. Achaeranea globosa, 5. Theridion flavonotatum 6. Theridula opulenta. Horizontal line: Mean. Vertical Box: Approximate Standard Deviation. Vertical Line: Range.

design, the web is consumed at daybreak and then rebuilt each night. Within each of these design types, there is a stratification of species within the canopy as depicted in Figures 2-2 and 2-3. Interestingly, the araneids which are at the hub primarily by night occur higher on the plant than do species which stay at the hub both day and night.

Levi has published many of the keys useful for identifying the species within this family (1971, 1975, 1976, 1977, 1980). Berman and Levi (1971) revised the genus Neoscona. The orb weavers I collected from corn fields are as follows:

Acacesia hamata (Hentz)

Acanthepeira sp.

Araneus miniatus (Walckenaer)

*Araneus pegnia (Walckenaer)

Araneus sp. indet.

Argiope aurantia Lucas

*Argiope trifasciata (Forsk.)

Cyclosa caroli (Hentz)

**Cyclosa turbinata (Walckenaer)

*Eriophora ravilla

*Eustala anastera (Walckenaer)

Gasteracantha cancriformis (Linnaeus)

**Gea heptagon (Hentz)

Hyposinga prob. rubens (Hentz)

Araneidae--continued:

Larina directa (Hentz)**Leucauge venusta (Walckenaer)*Mangora gibberosa (Hentz)Mangora spiculata (Hentz)Mecynogea lemniscata (Walckenaer)Micrathena sagittata (Walckenaer)*Neoscona arabesca (Walckenaer)Scoloderus cordatus (Taczanowski)Tetragnatha caudata Emerton**Tetragnatha laboriosa HentzWagneriana tauricornis (O. P.-Cambridge)

Araneus pegnia, Eriophora ravilla, and Neoscona arabesca form the bulk of the third type of orb web builder described above in which the spider hides in a retreat within a curled leaf near an upper corner of the web. Araneus pegnia was most common in the 1982 Archer fields where adults were collected during the final stages of the crop period. This spider was infrequently collected at all fields studied in 1983 and 1984, including those at Archer.

Eriophora ravilla took the place of A. pegnia at the 1983 and 1984 fields. It was particularly common at Orange Heights in 1983 and Archer in 1984. The majority of specimens collected were small juveniles, 4mm in length or less.

Adults, which are large spiders nearly 12mm in length, were collected in the months following harvest on nearby shrubs.

Neoscona arabesca, on the other hand, was collected at all six fields but especially at the Archer fields in 1983 and 1984. Although most of the specimens collected were again small juveniles, a number of adult females and males were found by harvest time. The prey range that I recorded for these three species was quite similar. Among the prey recorded were small coleoptera such as Sitophilus and Cal-lida spp., Braconidae, Agromyzidae (leaf mining diptera), Ottitidae, Geocoris, Orius, and Cicadelidae. Mature spiders have been observed to take moths, but are too small during the growth and flowering stages when Spodoptera and Heliothis are important.

Argiope trifasciata was common in both 1982 Archer fields and present at the other four fields at low populations, but a number of large juveniles and an adult female were collected. The web of these large spiders (up to 17mm) was usually attached to the lower half of the plant, and spanning two adjoining plants or even across the furrow. The plane of the flat orb makes an angle of about 60 degrees with the ground and has a characteristic zigzag stabilimenta. A frequent component of the diet is grasshoppers (Comstock 1948), but I also recorded coleoptera and cicadelids.

Cyclosa turbinata was the most abundant araneid in the 1982 Archer corn fields but was only moderately common at the other fields. The web of this species is markedly characteristic and is also helpful in determining the prey used. Rather than dropping the dried remains of consumed prey out of the web, this spider incorporates them into the web along the vertical axis. The spider is similarly colored and shaped as this debris, and so is difficult to spot as it sits upon it. By placing this clump of dead insects in a dilute solution of bleach to dissolve the silk, I was able to extract and identify the contents. Like many spiders, Cyclosa has powerful gnathobases which effectively crush the cuticle of prey so that for many prey items I was able to determine only the family: Chrysomelidae, Sitophilus, Dolichopodidae, Agromyzidae, Ottitidae, Braconidae, Aphidae, Cicadelidae and alate Formicidae.

Eustala anastera, in its mature stages, which I found only on adjacent shrubs and weeds, behaves like A. peggia and N. arabesca by hiding in a retreat by day. But as early instar juveniles in the corn field, these spiders were mostly found sitting at the hub by day. They reached their greatest abundance on the corn plants late in the season as the plants were entering senescence, constructing their webs among the spikes of the tassel. Even when the plants were dried and brown these spiders continued to use the tassels for their orb webs.

Gea heptagon was consistently captured at all six corn fields. This easily recognized spider has a black, five-or seven-sided splotch on the dorsum of the abdomen from which it gets its name. The web is vertical and nearly always in the bottom third of the canopy (see Figure 2-2) with some of the support strands attached to the ground. This spider's web of tough silk was also frequently found suspended from weeds and debris beneath the canopy.

Despite being the most common araneid in my collections of corn field spiders, no adults of Gea heptagon were collected, and only a few late instar juveniles. Adult specimens were encountered in the corn field after harvest beneath tall weeds, but also in the early spring before the field was mown and harrowed. The prey I found in their webs were mostly flying insects, but I also observed this spider to take an ant that had blundered into one of the strands attached to the ground.

Leucauge venusta became numerous in the corn fields at the Archer and Gainesville fields in 1984 after the canopy had developed sufficiently to shade the understory. However, these spiders were mostly quite small, and so did not reach maturity before the corn was harvested. Even as the corn plants were entering senescence and thus allowing more light to penetrate to the soil, these shade loving spiders began to disappear. This is a reflection of this

spider's normal habitat in north Florida, the shaded understory of hammocks.

Its web of finely meshed, exceeding delicate silk, is constructed parallel to the ground at about mid-level in the canopy. The web sways freely in the breeze which helps it intercept small flying diptera (Craig et al. in press) and which may also allow it to be supported by the wavering corn leaves.

Tetragnatha laboriosa was the most abundant of the Araneidae which build a horizontal web, and the second most abundant orb weaver over all. The greatest portion of the specimens collected were quite small and in practice could not be reliably separated from the other species of Tetragnatha. But since adults of other species were not collected in the vicinity of any of the corn fields, except for swampy Orange Heights, I feel justified in assuming that most of those collected in the corn field were in fact T. laboriosa. As a group, Tetragnatha is normally found in marsh or swamp habitats; T. laboriosa is the major exception.

I recorded a number of prey for this spider including the alate forms of Aphidae and Formicidae, Cicadelidae, Braconidae, Cecidomyiidae, and Agromyzidae. LeSar and Unzicker (1978) in a study conducted in Illinois also made considerable contribution to the biology and known prey range of Tetragnatha laboriosa. There it was the most abun-

dant spider in soybean fields. Culin and Yeargan (1982) also detailed the prey range for this spider in soybeans.

T. laboriosa showed an interesting stratification in the crop canopy as a function of its size. The smallest spiders, which are less than 1 mm in length occur more often in the lower canopy, and the adults, which reach 7 mm, in the upper canopy. The correlation between body length and the height of the web in the canopy as shown in Figure 2-5 was significant ($r=.54$, $p < .01$, $N=39$). This was the only spider which showed a significant correlation (negative or positive) between body size and position in the canopy.

Agelenidae. The funnel web spiders, or Agelenidae, were rare spiders in the corn field itself, but were quite common in the wooded borders. Just four specimens were collected, and these were near the border areas of the corn field. A Cicadellidae and an early instar nymph of a Gryllidae were seen to be taken as prey. Identification of these spiders is based on adult characters of the genitalia and so I am sure only of the genus:

Agelenopsis sp.

Hahniidae. The Hahniidae were another uncommon family of spiders in Alachua County corn fields, but were nonetheless successful colonists in that they reached maturity

Figure 2-5. Vertical stratification of *Tetragnatha laboriosa* on the corn plant as a function of body length.

before harvest. These spiders are easily recognized by having six spinnerets arranged along the posterior margin of the abdomen and by the construction of their web. The tiny, delicate sheet web is spun over the soil; the spider itself hides under an earthen clod or among the prop roots of the corn plant, running out over the top of the web to secure prey. Specimens, up to 3mm in length, were captured at the Archer and Gainesville fields only.

Mimetidae. The Mimetidae, unlike most spiders, do not normally eat insects. Instead they prey on other spiders, particularly web dwelling species, by stealthily climbing into the host's web. Numerous long, curved spines on Legs I and II are used by the mimetid to preclude an attack by its prey until its own venom has taken affect. I frequently found a trail of empty webs, particularly of Achaearanea globosa, at the end of which I found Mimetus in the web of its most recent victim. Surprisingly, Mimetus sp. was among the common spiders at Archer in 1983; it was present but rare at the other fields. At least two species of Mimetidae were collected with specimens taken from all six fields:

Ero leonina (Hentz)

Mimetus sp.

Pisauridae. Only twelve specimens of Pisauridae were collected from the corn field during the study. All of the specimens were collected as early instar juveniles from the lower surfaces of leaves in the lower half of the plant. Two species were identified using the keys in Carico (1972):

Dolomedes sp.

Pisaurina sp. prob. mira (Walckenaer)

Lycosidae. The wolf spiders, family Lycosidae, are the dominant group of hunting spiders on the soil in many agricultural situations (Whitcomb et al. 1963). Most species are active and hunt at night when reflective eyes make the majority easy to find with a headlight. Pardosa spp. however are most active during the daylight hours while others are largely subterranean, such as Geolycosa, Lycosa carolinensis and Lycosa lenta and so the populations of these were probably underestimated by my sampling techniques.

Identification of lycosids to the level of species relies heavily on characteristics of the genitalia and so juveniles cannot always be placed with confidence. Using the keys of Dondale and Redner (1984) I was able to identify adult Pardosa, and with practice, I was able to separate the juveniles of the four Pardosa species; this was made easier

by comparison with juveniles reared from positively identified adults. Most members of the genus Lycosa were identified as L. lenta because it was the only identified adult species found in the corn field at night by head light. Identification of Pirata was aided by Wallace and Exline (1978).

Fourteen species of lycosids were distinguished from my collections in corn fields:

Allocosa floridana

Lycosa rabida Walckenaer

Lycosa carolinensis Walckenaer

Lycosa hellulo Walckenaer

*Lycosa lenta Hentz

Lycosa amophila

*Pardosa pauxila Montgomery (=georgae)

Pardosa littoralis Banks

**Pardosa milvina (Hentz)

**Pardosa parvula Banks (=saxatilis)

Pirata allapahae Gertsch

Pirata sp. A

Pirata sp. B

Genus et sp. indet.

Lycosa lenta, as an adult, is a large nocturnal hunter of the soil surface where I found it preying on other wolf

spiders and crickets. The majority of specimens collected were taken at the Archer fields, all as early to middle instar juveniles. All quantitative sampling was conducted between 0730 and 1130 hours when L. lenta is usually inactive and in hiding beneath dead corn leaves or under clods of earth. Using a head light at night I could find L. lenta adults at low densities, particularly in border areas and along irrigation rows. I rarely found adults roaming in under the corn canopy. As do all the Lycosidae, L. lenta females carry the egg sac attached to the spinnerets until the spiderlings emerge. The spiderlings crawl onto the dorsum of their mother and then disperse over a period of several days as she roams and hunts. Lycosa lenta frequently prey on other lycosid spiders, either con- or heterospecifics (Gowan, 1985).

Pardosa milvina, with 333 specimens collected during the study, was the single most abundant spider in the corn fields. All stages of this species were present in the fields nearly throughout the year, but were scarcest at planting and just after cultivations. Recolonization occurred rapidly through ballooning and running over the soil. Adult females can deposit spiderlings over a large area as described above for L. lenta. Dense populations of P. milvina were found in the cattle pastures (especially over grazed ones with barren patches of soil) and in the

recently fallow fields that were integral parts of the Archer and Orange Heights ecosystems.

The behavior of Pardosa milvina, as I observed it in the field, was quite variable. Most specimens were collected running over the soil, or among the basal leaves and prop roots, but a significant number were found high on the foliage, even on the corn silk. I recorded them to take prey while on the plants, specifically corn leaf aphids (Rhopalosiphum maidis), but they also take water that collects in the leaf axils during the morning dew. Another specimen was found hanging from the corn silk while in the process of ecdysis; a number of exuviae were also found similarly positioned.

Pardosa as a group seem to require a moist environment; this was dramatically demonstrated at the Gainesville field. From the middle of May through the beginning of June, just as flowering was about to start, a three week long period of very dry weather nearly destroyed the crop during which the population of Pardosa milvina plummeted (see Figure 2-11). When rain returned, the crop quickly recovered but the P. milvina did so only slowly. In this case I believe that the absence of cattle pastures and fallow fields was responsible for the failure of the population to recover. Another facet of recolonization is that Pardosa ballooned only rarely during May through August (see Chapter III).

Pardosa pauxila and P. parvula were common to abundant wolf spiders, notably during 1983. During the mature period at the Archer field, P. parvula was the most frequently captured wolf spider, while at Orange Heights Pardosa pauxila was among the most commonly collected. The behavior of these spiders was very similar to P. milvina's such as climbing up into the plants to drink dew water and ecdysis while hanging from the silk.

Oxyopidae. The lynx spiders, family Oxyopidae, are largely diurnal hunting spiders which rely on a combination of sight and acute tactile reception to capture prey. Silk is used in construction of the egg sac and in ballooning, but not for snaring prey. Identification of Oxyopidae is aided by Brady (1964). One species made up the bulk of the spiders in this family collected from corn fields:

Oxyopes salticus Hentz

**Peucetia viridans (Hentz)

Peucetia viridans, the green lynx spider, entered the fields during April at the end of its ballooning period (see Chapter III). It was one of the most common spiders when the plants were small, and this population level that was achieved in April remained relatively constant through the season until senescence, when the spiders moved onto the

emerging weeds (see Chapter IV). The greatest numbers of P. viridans occurred at the Archer fields but were virtually absent at Orange Heights. They reached 7mm in length by harvest time and so were the largest of the common species. These are strong predators in the corn field preying on Chrysomelidae, Scarabaeidae, Cucurlionidae, Diptera and small bees.

Adult P. viridans, which appear in late July to August, specialize on pollenators as prey. From the blossoms of Eupatorium, Monarda, Indigofera hirsutum and Bidens alba they catch numerous honey bees and even large wasps. The spiderlings hatch in the late fall and become soil surface wanderers until early spring (Whitcomb 1985) when they can be found on spring weeds, low tree branches and shrubs. They balloon frequently during this time (see Chapter III) and remain in the first post emergence instar. Soon after their arrival in the corn field they molt to the second instar and cease to move through the air. Peucetia viridans is an example of a spider that despite not reaching maturity while a part of the corn field community can be an abundant spider depending on the weeds that grow nearby. The presence of large areas of late summer weeds will provide numerous offspring for next year's crop.

Gnaphosidae. Among the webless hunting spiders, the Gnaphosidae are elongate, fast running, largely soil surface hunters. Gnaphosa serricata, the only common species in northern Florida corn fields, hides beneath the soil by day and roams by night. Pitfall traps set in the corn field efficiently captured these arachnids. I did not record any predation by these spiders, but a spider wasp (Pompilidae) was captured taking a penultimate female of G. serricata. Gnaphosa serricata was the only one of the following species for which more than one specimen was collected, and then only from the drier Archer and Gainesville fields (Platnick and Shadab, 1975):

Drassodes sp.

Drassyllus sp.

*Gnaphosa serricata (L. Koch)

Poecilochroa variegata (Hentz)

Genus et sp. indet.

Clubionidae. The sac spiders, family Clubionidae, have some common and important species in agricultural fields. These spiders have, for example, been recorded to feed on the eggs of Heliothis (Peck and Whitcomb 1970) and the larvae of other lepidoptera. Most species of Clubionidae hide by day in well concealed sacs constructed of silk. The sacs can be in a rolled or torn leaf, in a folded blade

of grass, or deep in the corn silk. If the plant is vigorously shaken, and sometimes only gently, the spider will almost always emerge from the sac running at high speed for some distance and then halt. If an empty sac is found during a visual search it is wise to look about for the spider which may be hiding nearby. Most species of Clubionidae are nocturnal, but several groups which apparently mimic wasps and ants are active in full sunlight. The driest corn fields at Archer had the highest numbers of clubionids, while the wettest, Orange Heights, had few. All of the Clubionidae make use of their acute tactile perception in the capture of prey. These species were found and identified using Edwards (1958), Reiskind (1969), and Platnick and Shadab (1974a, 1974b):

Castianeira sp. A

Castianeira sp. B

**Chiricanthium inclusum (Hentz)

*Clubiona abbotii L. Koch

Clubiona procteri Gertsch

Micaria sp.

Myrmecotypus lineatus (Emerton)

Phrurotypus minutus

Scotinella sp.

*Trachelas deceptus (Banks)

Trachelas similis O.P.-Cambridge)

Chiricanthium inclusum and its role in agricultural fields was studied by Whitcomb et al. (1963) and Peck and Whitcomb (1970) who found it to be an important predator in cotton fields. But in Alachua County corn fields it was common only at the Archer fields where it was among the top ten most common spiders. From the time when the corn silk emerged until it rotted off during the mature phase, C. inclusum was found hidden deep in this silk. When the silk was not available, it preferred leaves tattered by Spodoptera frugiperda or in the recessed midrib on the lower leaf surface. But on other plants these spiders normally tie several nearby leaves together (or use ones already tied together by pyralid larvae) and build their silken retreat within. Thus, home sites for this spider on the corn plant are marginal and could be a factor that limits this spider's numbers in the corn field. Otherwise the corn plant should provide adequate prey, such as lepidoptera, as evidenced by my finding reproducing adults on the corn plants.

Clubiona abbotii and C. procteri are quite similar even as adults, and so I have not attempted to separate the juveniles. Five adults of C. abbotii were found; one of C. procteri. Again, these spiders were absent from the Orange Heights field and were only sporadically common at Archer. Yet these spiders were among the most common species

captured as ballooners (see Chapter III). Only two nests of this species were found in the corn silk; the remainder were in the depression along the midrib on the lower surface of the corn leaf or in the leaf axil. I did not record any feeding by these species, but one female was found with an egg sac.

Trachelas deceptus and T. similis are also not easily distinguished as juveniles. Here five adults of T. deceptus were identified and one of T. similis. Trachelas are generally robust spiders with the first pair of legs longer than the others and with the cephalothorax and forward legs a deep maroon color which fade to pale towards the posterior of the animal. These spiders were regularly encountered only at the Archer fields (both species), hiding deep in the leaf axils, especially of the lowest leaves. I found no reproduction occurring and did not record any prey.

Anyphaenidae. In many ways the Anyphaenidae resemble the clubionids and it can be troublesome for the novelist to distinguish the two. The most important and reliable character is the placement of the spiracular slit on the venter of the abdomen. In clubionids it is just anterior to the spinnerets, while in the anyphaenids it is placed a half or two thirds of the way anteriorly towards the epigastric furrow. The spiracle is very faint and requires a good

microscope to see. Another character which is sometimes useful is the notched trochanter (Roth 1964). Among the species found only Aysha spp. was collected infrequently; the others were rare. The silk retreats, which are also similar to the clubionid's, were most frequently found in the tassel. Again Aysha spp. were frequently caught on the traps used to monitor aerial dispersal indicating that the corn plants do not provide a suitable niche. Four species were identified using the keys published in Platnick (1974):

Aysha velox (Becker)

Aysha gracilis (Hentz)

Teudis mordax (O.P.-Cambridge)

Wulfila saltibunda (Hentz)

Thomisidae. The crab spiders, family Thomisidae, are so named for their elongated anterior legs and sideways movement characteristic of true crabs. Thomisid spiders position themselves at key positions on their substrate so as to maximize the encounter rate with potential prey. For many species this means sitting in the flower of a plant to capture pollinators and other flower feeding insects. Despite their cryptic coloration, species which frequently hunt at the inflorescence of a plant are not restricted to that position. They can also hunt from the growing terminals or leaf petioles (Plagens 1981). The identification

of the Thomisidae is greatly aided by the revision by Gertsch (1939). Only one of the following five species collected was common enough to warrant separate discussion:

Misumenoides formosipes (Walckenaer)

**Misumenops celer (Hentz)

Misumenops oblongus (Keyserling)

Xysticus sp. A

Xysticus sp. B

Misumenops celer was frequently the most abundant foliage layer hunting spider. The majority of captures were during the flowering and early mature periods when the spiders were almost always captured on the inflorescences, either the male tassel or the female silk. The age structure of this species was greatly skewed towards the smallest instars which arrived by ballooning and then departed the same way once the flowers stopped attracting prey (see Chapter III). For these early juveniles, the principal prey, as I recorded it, were thrips, followed by minute diptera. Larger spiders were captured while feeding on Orius, Geocoris, Agromyzidae and other hunting spiders including conspecifics. Plagens (1981) found hymenopterous parasitoids also to be a major part of this spider's diet. Adult males and females were collected in the corn fields but no females with eggs were found.

Philodromidae. For many years the family Philodromidae was classified as a subfamily within the Thomisidae. However, recent work on the ultrastructure of the eyes combined with a host of other character differences has convinced most arachnologists that they are correctly separated (Homann 1971,1975). The hunting strategies differ markedly also. Philodromids run very fast and legs provided with adhering scopulae. They pursue prey for short distances after detecting their presence through vibrations and are rarely found on or near the flowers. Many species are found on the stems and bark of woody plants. I captured just three specimens of this family in the corn field, but I may well have missed some. They run to the other side of the plant stem or leaf if they detect movement and can cling to surfaces with surprising tenacity when the plant is shaken. Identification was aided by Dondale and Redner (1961, 1968).

Philodromus keyserlingi Marx

Salticidae. As sophisticated as the Araneidae are in the construction of webs, so are the Salticidae in the visual pursuit of prey. The eyes are certainly the most sophisticated of any arthropod eye and rival the vertebrate eye in their ability to detect form, color, movement,

orientation and distance (Homann 1971). Not only does this aid them in locating prey, but also in the safe capture of prey. By grasping prey such as caterpillars or ants at precisely strategic points (Edwards et al. 1974) the prey's defenses are rendered ineffective.

The Salticidae were common and well represented by species at the Gainesville and Archer fields, but were nearly absent from the Orange Heights field. Several species are avid ballooners (Horner 1975 and Chapter III) even as middle to late instars which can mature quickly on abundant prey in their new surroundings and begin producing offspring. Eighteen species of salticids from corn fields were identified:

- Corythalia canosa (Walckenaer)
- Habronatus brunneus (Peckham & Peckham)
- Habronatus trimaculatus Bryant
- **Hentzia palmerum (Hentz)
- Marpissa dentoides Barnes
- Lyssomanes viridis (Walckenaer)
- **Metaphidippus galathea (Walckenaer)
- Peckhamia americana (Peckhams)
- Phidippus apacheanus Chamberlin & Gertsch
- Phidippus audax (Hentz)
- *Phidippus regius C.L.Koch
- Phidippus clarus Keyserling

Salticidae--continued:

Phidippus pulcherrimus Keyserling

Phidippus putnami (Peckhams)

Synageles sp.

Thiodina sp.

Zygoballus rufipes Peckhams

Hentzia palmerum was the second most abundant salticid collected in the corn fields. The males of this species have the chelicerae greatly elongated and porrect (directed forward). Early juveniles through adults of this species were found in the corn fields, particularly on the silks or tassels. At Orange Heights, this spider was nearly absent from the corn plants, but they became fairly common on the weeds in that field by September (see Chapter IV). The prey for this species consisted largely of soft bodied insects such as agromyzids, aphids, Orius and thrips.

Metaphidippus galathea vied with Misumenops celer as the most common foliage hunter. Like both M. celer and H. palmerum these spiders concentrated their activity on the inflorescences. Some arrived in the corn fields early enough to mature and begin producing offspring. First instar juveniles that emerge before the flowering is over find abundant thrips and diptera in the silk and on the tassels. Those that emerge later move to the emerging weeds

such as Indigofera, Cassia and Amborsia where they become one of the most common species (see Chapter IV). Horner and Starks (1972) found that M. galathea has a relatively short life cycle, reaching maturity in 6 to 7 months. Female spiders produced a mean 8.3 egg sacs over her life span.

Like salticids in general, Metaphidippus hunts primarily by sight, taking an assortment of prey similar to Hentzia's but it can adopt alternate hunting strategies. I found M. galathea pulling diptera larvae from the rotting frass left by corn ear worms.

Just two specimens of Metaphidippus were collected from the corn plants at the Orange Heights field where it was also less common than H. palmerum on the weeds following harvest.

Phidippus regius is a member of a large genus of common, large jumping spiders. These spiders produce large quantities of offspring (Edwards 1980) that balloon frequently (see Chapter III) and so it is not surprising that they occur with regularity in the corn field. Some specimens of this and the other five identified species reach the middle instars. No adult Phidippus of any species were collected. Like Hentzia and Metaphidippus these spiders were most frequently collected in the silk or on the tassels. Prey included diptera and Cicadelidae. Muniappan and Chada (1970) found P. audax to be a potential biological control agent of green bugs (Aphididae) in sorghum.

Community Structure

Species Abundance. The rank abundances of the individual species during the growth, flowering and mature stages are presented for each of the six fields in Figures 2-6, 2-7, 2-8, 2-9, 2-10 and 2-11. Just one spider was common in all six fields, namely Pardosa milvina. Four spiders, Misumenops celer, Achaeearanea globosa, Tetragnatha laboriosa and Metaphidippus galathea, were common in five of the six fields. Gea heptagon, Peucetia viridans, and Uloborus glomosus were common in four of the six fields while eight species were common in three of the fields. Most species which were common in one field were at least present in the other fields. Thus, differences between fields were mostly in the relative frequencies of the major species and in the list of rarely captured species.

Spider Families. The family composition of spiders in the six fields are presented in Figures 2-12, 2-13 and 2-14. Even at this taxonomic division, there were considerable differences between the six fields. This could be a reflection of the general strategies for surviving used by the different spider families contrasting with the physical and biotic conditions presented by the surrounding habitats. The Lycosidae, for example are favored by the presence of

Figure 2-6. Principal species and percent rank abundance of spiders in field corn during three phenological periods at Archer, Florida, 1982, Field A. Growth (A), Flowering (B), Mature (C).

Figure 2-7. Principal species and percent rank abundance of spiders in field corn during three phenological periods at Archer, Florida, 1982, Field B. Growth (A), Flowering (B), Mature (C).

Figure 2-8. Principal species and percent rank abundance of spiders in field corn during three phenological periods at Archer, Florida, 1983. Growth (A), Flowering (B), Mature (C).

Figure 2-9. Principal species and percent rank abundance of spiders in field corn during three phenological periods at Orange Heights, Florida, 1983. Growth (A), Flowering (B), Mature (C).

Figure 2-10. Principal species and percent rank abundance of spiders in field corn during three phenological periods at Archer, Florida, 1984. Growth (A), Flowering (B), Mature (C).

Figure 2-11. Principal species and percent rank abundance of spiders in field corn during three phenological periods at Gainesville, Florida, 1984. Growth (A), Flowering (B), Mature (C).

nearby cattle that produce habitat and prey for Pardosa spp. The Linyphiidae are favored by wet conditions, like those surrounding the Orange Heights field. And the visually dependent Salticidae are favored by old field weeds and shrubs where light and prey are plentiful.

Species Diversity. Species diversity, measured either as H' or as the total number of species, reached its peak in the corn fields just as the corn reached the mature stage. The diversity measurements for all six fields and each phenological period are presented in Figure 2-15. The highest diversity measurement was in the mature stage at the Gainesville field when I found 61 species and $H'=4.08$. As would be expected the diversity is lowest when the corn plants are small.

As the corn plants grow, many attributes of the field's complexity emerge. A gradation of light, humidity and wind is produced by the developing canopy. An array of geometries for the web building spiders is created, as well as an increasing variety and abundance of potential prey. Also, the weeds begin to appear between the corn plants providing sources of other potential prey as well as additional structural supports. Robinson (1981) and others have demonstrated the importance of geometry in determining diversity and species composition.

Figure 2-12. The major families of spiders collected in field corn at Archer, Florida during 1982. Field A (Top) and Field B (Bottom).

Figure 2-13. The major families of spiders collected in field corn during 1983 at Archer, Florida (top) and Orange Heights, Florida (Bottom).

Figure 2-14. The major families of spiders collected in field corn during 1984 at Archer, Florida (top) and Gainesville, Florida (Bottom).

Figure 2-15. Species diversity of spiders as measured by H' in six corn fields in Alachua County, Florida. Archer, 1982 Field A (A); Archer, 1982 Field B (B); Archer, 1983 (C); Orange Heights, 1983 (D); Archer, 1984 (E) and Gainesville, 1984 (F). Phenological periods: G = Growth, F = Flowering, M = Mature.

Stratification. Six layers within the corn field canopy are here defined: (1) the soil surface, (2) the base of the corn plant where it meets the soil, including the prop roots, (3) the lowest third of the foliage, (4) the middle foliage from the fifth to the ninth leaves (numbered from the base), which includes the developing ear, (5) the top foliage and tassel, and finally (6) the weeds beneath the corn plants. The results of this breakdown are presented in Figures 2-16, 2-17, and 2-18.

The seasonal dynamics of each of these strata is a function of each individual species' population dynamics. But since several species may be dependent on the same environmental and biotic variables, the strata dynamics can reveal the nature of those variables. Thus, a number of these variables were revealed through this analysis when combined with general field observations.

Consider first the two lowest strata, that is those spiders which inhabit the soil surface, and those that live around the base of the corn plant. An important point here is that a single species is not necessarily restricted to any one strata, but rather the opposite is true; most species were found in more than one layer. Excluding Orange Heights, these strata have a small representation during the growth stage and then a modest decline in numbers by the flowering stage and finally a sharp increase through the mature stage. There are at least three things that

contribute to this movement. The first of these factors is the cultivation of the field. One of the main purposes of cultivations is weed control. This is achieved by turning the soil over and breaking it up so as to bury most of the weeds, expose the roots of others and to allow the soil surface to become dry and inhospitable for germinating weed seeds. This process is detrimental to spider populations at or near the soil surface by burying many of them directly, but also by burying their food supply, namely the insects associated with decaying plant debris from the previous season. Cultivation has a similar deleterious effect on the Carabidae in crop fields (House and All 1981).

Second, the decay of plant debris in the soil, which is delayed during the cool and damp winter, accelerates at planting when warm conditions return, thereby increasing the supply of detritivores available for the soil surface spider community. This material is rapidly exhausted however, and is not replaced until flowering, when great quantities of corn pollen are shed, much of which falls to the ground. The pollen feeds numerous Psocoptera and Collembola which later feed and reproduce upon the dying corn leaves at maturity.

The dynamics of these two lowest strata of spiders in the Orange Heights field are radically different from that in the other five fields largely because of the contrasting edaphic conditions. Under wet soil conditions, like those

Figure 2-16. Stratification of spiders in the corn field canopy during 1982 at Archer, Florida, Field A (A) and Field B (B).

Figure 2-17. Stratification of spiders in the corn field canopy during 1983 at Archer, Florida, (A) and Orange Heights, Florida (B).

Figure 2-18. Stratification of spiders in the corn field canopy during 1984 at Archer, Florida (A) and Gainesville, Florida (B).

at Orange Heights, the effectiveness of cultivation in controlling weeds is diminished considerably. Large clods of soil and sod remain upright and unfragmented, weeds with damaged root systems can regenerate, and the soil surface remains moist and ideal for seedling regrowth. The general ineffectiveness of weed control at Orange Heights is further reflected in the greater numbers of spiders associated with weeds. In addition, wet heavy soil is even more effective at delaying the decay of plant debris during the winter thus allowing an even larger production of detritivore prey with the advent of warm temperatures and the aeration provided by the cultivator.

Another major difference between the vertical stratification of spiders at Orange Heights and the other fields is a lag in the numbers of spiders inhabiting the middle and upper foliage. In the immediate vicinity of the Orange Heights field only a limited area was left as annual, full sunlight weeds which could serve as nurseries for spiders adapted to the high light and wind conditions present in the upper corn field canopy. The increase in upper and middle foliage spiders at maturity coincided with the mowing of these weeds.

The lag in the upper foliage hunters at Orange Heights was paralleled by much greater numbers of spiders in the lower foliage. Sources for shade dwelling spiders were

abundant in the area as under story herbs and shrubs in the slash pine plantations surrounding the field.

The stratification of the web building spiders was presented in Figures 2-2, 2-3 and 2-4.

Age Structure. The age structures of the spiders collected in the corn fields are presented in Figures 2-19, 2-20 and 2-21. At the Archer and Gainesville corn fields, during each phenological period, juvenile spiders outnumbered the adults by 2:1 or 3:1, and the seasonal trends were approximately parallel. Orange Heights on the other hand saw more than half the spiders collected during the growth period represented as adults, and just under half were adult during the flowering and mature stages. This difference is largely related to the proportion of the spiders belonging to the family Linyphiidae.

Abundant Linyphiidae at Orange Heights were favored for at least two reasons, both related to the wet soil conditions. First the soil and weeds were disrupted less than at the other fields because of the lower efficiency of the cultivator. This permitted a greater number of these largely soil surface dwelling species to escape destruction and to find suitable habitat. Second, since the Linyphiidae are generally favored by a damp microclimate, ballooning spiders would be attracted by the favorable physical conditions that would not appear in the other fields until after the canopy had developed. Also, the Linyphiidae are favored

Figure 2-19. Age structure of spiders in corn fields during 1982 at Archer, Florida, Field A (A) and Field B (B).

Figure 2-20. Age structure of spiders in corn fields during 1983 at Archer, Florida (A) and Orange Heights, Florida (B).

Figure 2-21. Age structure of spiders in corn fields during 1984 at Archer, Florida (A) and Gainesville, Florida (B).

by the swampy conditions in the habitat surrounding the Orange Heights field, and so were a major component of the species pool available for colonizing the corn field.

Guild Analysis. A guild, as defined by Root (1973), is a group of functionally similar species. The species included in a guild should exploit a similar resource in a similar way (Landers and MacMahon 1980). Of course the breadth of a guild then will depend on the degree of overlap between the guild species, since, it is assumed, that no two species exploit exactly the same resource in exactly the same way.

For this analysis six guilds were defined: (1) soil surface hunters; (2) foliage hunters, diurnal; (3) foliage hunters, nocturnal; (4) web spinners on the soil surface; (5) web spinners around base of plant; (6) web spinners from foliage layer. The families and genera that are included in these guilds are listed in Table 2-2, and the results of this analysis are shown in Figures 2-22, 2-23, 2-24, 2-25, and 2-26.

Again, excluding the Orange Heights field, the dynamics of these guilds through the season are remarkably similar between fields and years, as seen in Figures 2-23, 2-25 and 2-26. This similarity can be a result of several different phenomena. The similarity may simply be a result of one or two dominant species in the "guild" that behave

Table 2-2. The guild definitions of spiders occurring in the corn fields of north central Florida.

SOIL SURFACE HUNTERS

Lycosidae: Lycosa spp., Allocosa spp., Pirata spp.,
Pardosa spp.

Salticidae: Corythalia canosa, Habronatus spp.

Clubionidae: Scotinella spp., some Casteniera spp.

Gnaphosidae: Gnaphosa

FOLIAGE HUNTERS--DIURNAL

Oxyopidae: Peucetia viridans, Oxyopes salticus

Thomisidae: all species

Philodromidae: all species

Salticidae: all species except those listed above under soil surface hunters

FOLIAGE HUNTERS--NOCTURNAL

Clubionidae: Chiricanthium inclusum, Clubiona spp.

Anyphaenidae: Aysha spp., Wulfila spp.

SOIL SURFACE WEBS

Linyphiidae: all species not listed under foliage layer webs

Theridiidae: Steotoda spp.

Hahniidae: Neoantistea spp.

Table 2-2--continued

BASE OF PLANT WEBS

Linyphiidae: mostly the same species as occur in the soil surface web guild

Theridiidae: Latrodectus mactans, Achaeranea globosa, sometimes Steotoda spp.

Hahniidae: occasionally Neoantistea sp.

Araneidae: Gea heptagon, occasionally other species.

Theridiosomatidae: Theridiosoma

FOLIAGE LAYER WEBS

Linyphiidae: Ceraticellus similis, Frontinella pyramitella, Florinda coccinea, Grammonota texana

Theridiidae: Theridion spp., Theridula opulenta, Coleosoma acutiventer, Argyrodes spp. occasionally Achaeranea globosa

Araneidae: most species

Uloboridae: Uloborus spp.

Dictynidae: Dictyna spp.

Figure 2-22. Guild structure of corn field spiders as a function of phenological period during 1982 at Archer, Florida, Field A (A) and Field B (B).

Figure 2-23. Guild structure of corn field spiders as a function of phenological period during 1983 at Archer, Florida.

Figure 2-24. Guild structure of corn field spiders as a function of phenological period during 1983 at Orange Heights, Florida.

Figure 2-25. Guild structure of corn field spiders as a function of phenological period during 1984 at Archer, Florida.

Figure 2-26. Guild structure of corn field spiders as a function of phenological period during 1984 at Gainesville, Florida.

independently of each other, but similarly between fields. This is a reasonable explanation for the soil surface hunters which are dominated by Pardosa spp., the diurnal foliage hunters which are dominated by Misumenops celer, Peucetia viridans and Metaphidippus galathea, and the nocturnal foliage hunters which are composed primarily of Chiricanthium inclusum.

But the similarity of a guild's dynamics between fields could also result from the many included species each responding similarly to changing conditions in the fields that are related to crop phenology, for example, the increasing structural complexity, the microclimatic trends produced by the growing canopy, or changes in the abundance and diversity of prey. This is the best explanation for the guild dynamics of the web building spiders of the soil, plant base and foliage. For the web builders of the soil, the shade provided by the expanding canopy improves the availability of moisture. The canopy provides a similar change in the environment provided to spiders inhabiting the base, while increasing the structural complexity for the support of the many types of foliage layer webs.

Spider Density

During this study I have expressed density of spiders in numbers per 10 plants. Since the planting density was recorded (4.3 plants / m² at Orange Heights and 2.4

plants/m² at all of the other fields) the density of spiders per unit area can easily be calculated. During the flowering and mature phenological periods spider density ranged from 22 spiders per 10 plants (9.5 spiders/m²) at Orange Heights to a low of 9.3 spiders per 10 plants (2.2 spiders/m²) at Archer in 1983. The much higher density of spiders at Orange Heights was due almost entirely to the abundance of Eperigone banksi. This compares to densities of 0.56 to 13.52 spiders/m² in strawberries (Dippenaar-Schoeman 1979) and 53 spiders/m² in mown hayfields (Dondale 1970).

Within Field Distribution Patterns

Since the location of each sample within the corn fields was known and the size (10 plants) was kept constant, analyses of the within field distributions of the spiders were performed.

The first analysis was of the variance to mean ratio utilizing the Index of Dispersion I_D , as provided in Southwood (1978) (see Table 2-3). If the distribution is in fact Poisson, then the value of I_D will not lie outside the limits of χ^2 for $n-1$ df as given in standard tables. Small values indicate a regular distribution, large values an aggregated distribution. This test could be conducted only for the most common species. Pardosa milvina maintained a random distribution throughout the season and tended toward a regular distribution in two of the sample sets.

Table 2-3. The variance to mean ratios for sample densities of common spiders taken in four corn fields in Alachua County, Florida.

Field	Genus species	Phenological Period		
		Growth	Flowering	Mature
Archer, 1983	<u>Pardosa milvina</u>	1.17	1.33	1.07
	<u>Pardosa parvula</u>	2.10	1.00	1.50
	<u>Peucetia viridans</u>	2.21	0.74	1.15
	<u>Metaphidippus</u> <u>galathea</u>	1.97	1.55	1.05
	<u>Misumenops celer</u>	2.00	1.98	1.46
	All Spiders	0.99	2.04	2.20
Archer, 1984	<u>Pardosa milvina</u>	1.10	0.62	0.60
	<u>Peucetia viridans</u>	0.93	0.95	0.73
	<u>Metaphidippus</u> <u>galathea</u>	0.86	1.11	0.88
	<u>Misumenops celer</u>	1.00	1.38	1.18
	<u>Chiricanthium</u> <u>inclusum</u>	1.00	1.19	1.70
	<u>Gea heptagon</u>	1.62	1.61	0.91
	<u>Tetragnatha</u> <u>laboriosa</u>	1.62	0.88	2.94
	All Spiders	1.46	0.99	2.55
		.		
Gaines- ville, 1984	<u>Pardosa milvina</u>	0.93	0.74	0.82
	<u>Metaphidippus</u> <u>galathea</u>	-	-	0.64
	<u>Peucetia viridans</u>	-	-	0.82
	<u>Misumenops celer</u>	-	1.51	1.39
	<u>Achaeranea globosa</u>	1.09	2.32	1.60
	<u>Gea heptagon</u>	-	0.95	1.07
	<u>Leucauge venusta</u>	-	1.37	1.47
	<u>Theridion</u> <u>flavonotatum</u>	-	2.00	2.27
	All Spiders	1.52	3.26	1.44
Orange Heights, 1983	<u>Pardosa milvina</u>	1.50	0.88	1.54
	<u>Pardosa pauxila</u>	0.82	1.40	1.56
	<u>Gea heptagon</u>	1.18	1.64	0.89
	<u>Eperigone banksi</u>	5.09	1.64	4.19
	<u>Meioneta</u> sp.	1.27	0.40	1.33

Significantly aggregated distributions ($p < 0.5$) were recorded for Achaearanea globosa, Theridion flavonotatum and Tetragnatha laboriosa. For these species, the aggregations were the result of females producing offspring which did not disperse far after hatching. Other species showed aggregated distributions early in the season which were probably due to uneven colonization of the field or uneven initiation of silking and flowering. Still other spiders showed aggregated distributions late in the season as the corn field began senescing unevenly.

The highest degree of clumping was shown by Eperigone banksi at Orange Heights. In this case early dense clumps of adult spiders were associated with clumps of sod which had not been successfully turned over by the plow. These clumps of spiders later produced numerous offspring which apparently were not induced to disperse far. Both E. banksi and A. globosa feed heavily on Solenopsis ants (see Table 2-5); since web building spiders tend to move in response to a lack of prey (Turnbull 1964) the abundance of their prey in the corn fields may explain their failure to disperse following eclosion.

Pieters and Sterling (1974) recorded $I_D = 1.71$ for all spiders combined in Texas cotton fields.

As Taylor (1984) points out, the spatial distributions of insects (and presumably, spiders) are dependent on both sample size and density. Thus, if my sample size had been

more or less than ten plants, a different picture of dispersion would likely have been observed, whereas the low spider densities in the corn field, probably kept most intra-specific interactions (influents of spatial dispersion) quite weak, except for Pardosa milvina.

By computing the correlation between the density of spiders in a set of samples with the distances of those samples from the border of the field, I hoped to discern border effects. A negative correlation would indicate that the spider was more abundant in the border areas, while a positive coefficient would indicate that the spider was more numerous in samples nearer the field center. This test was also used for all spiders lumped together and for the number of species in each sample.

Only one calculated coefficient was significant, that for Peucetia viridans ($r = -0.63$; $p < 0.5$). P. viridans ceases to disperse by ballooning (see Chapter III) at about the time the corn plants are emerging. Thus some individuals may subsequently bridge or walk into the field from adjacent plants, particularly the oak trees in the fence rows (see Chapter IV). For the other spiders there was a general, but only slight, tendency for a higher frequency in border samples (in 50 of the 80 tests the correlation coefficient was negative). The relationship between a sample's distance from the border and the number of species in it was not significant. This indicates that for most spiders

colonizing north Florida corn fields are good dispersers. Another possibility, however, is that border effects are minimal beyond a short distance (say 10 rows).

The Corn field as a Habitat for Spiders

In the faunal description above, the discussion under the major species included mention of how various attributes of the corn field ecosystem compliment or conflict with each spider's biological and physical requirements. Each potential colonizing spider responds to the corn field's attributes as a function of its particular phenotype and developmental state. But since many species were observed so infrequently, a general discussion of the corn field attributes that have the potential for structuring the spider community is desirable.

Microclimate. The microclimatic conditions presented to colonizing arthropods by cultivated row crops are usually harsh and demanding (Cloudsley-Thompson 1962). Successful colonists must withstand significant daily and seasonal changes in the microclimate. The developing canopy is the driving variable, shading the soil surface, decreasing wind speeds, increasing relative humidity, and eventually decreasing the daily fluctuations in both temperature and humidity. Upon senescence, the leaves of the crop droop or abscise thus returning this ameliorated microclimate nearly

full circle to one that is again physically harsh. For the corn fields in northern Florida this cycle required just under four months time.

Moisture and humidity requirements of some species have wider tolerances than others, or else the tolerances may change with their development (Luczac 1979 and Cherrett 1964). The individual effects of the microclimatic variables, humidity, temperature, wind speed and insolation, are interdependent and thus not easily separable without detailed experimental evidence. Further, their effects may be either direct or indirect. Direct effects which may preclude or favor different spider species include desiccation early in the season or disease brought on by excessive humidity when the canopy becomes closed. Other spiders respond to microclimatic variables as token stimuli for locating their optimum habitat. Cherrett (1964) found that the araneid Meta merianae, for example, oriented towards darkness because that is where its preferred web sites and prey are located.

Indirect effects of the corn field microclimate are those which determine the array of available prey. I found for example that dry conditions favored tenebrionid beetles and ants while damp weather favored Collembola, Psocoptera and small Diptera.

During the hottest, driest periods of the day, hygrophilous spiders which orient towards the higher humidity

found deep in the corn silk or close to the undersurface of the leaves can survive. During the extended dry period at the Gainesville field Metaphidippus galathea, Phidippus spp, Chiricanthium inclusum and Misumenops celer wedged themselves deep in the corn silk. When corn is stressed for water the leaves curl, thus creating a more protected spot for spiders which must avoid highly desicating situations.

The corn plant is an efficient collector of dew, as an early morning entry into the field will attest, but the collected dew is also stored through much of the day in the leaf axils. This water is available to spiders which can imbibe it from the edge of the leaf base, such as Pardosa milvina which was frequently observed taking water from this reservoir. Small spiders can enter through the ligule while larger, stronger species can push through it into the leaf sheath cavity (e.g. Trachelas). Dew and rain water that drip off the tips of corn leaves create circular depressions (4 - 10 mm in diameter) in the soil below that were used by linyphiids to suspend their webs. This seemingly minor effect might be quite important to these sheet web builders which frequently require rather specific structures for the erection of their tiny sheet webs (Thornhill 1983).

Agricultural practices are an important modifier of the microclimates created by the corn field. Among the most important of these is the use of irrigation. During drought periods, which were severe on the sandy soil at the Archer

fields, crop fields present a particularly xeric habitat. Spiders which orient towards moisture were concentrated in the shaded areas where reduced insolation had reduced evaporation. On the other hand, when the field was irrigated moisture seeking species migrated into the field, especially from the annual weeds that had dried.

The amount of organic matter in the soil, as well as the degree of soil compaction, will of course influence water relations at the surface. When the weather had been dry, clumps of plant debris were found to be damp inside; here clubionids, gnaphosids, lycosids and linyphiids were found taking refuge. Soil types that fissure upon drying create refugia in which spiders such as hahniids can await better conditions. Dry, powdery soil will favor those species which can burrow deep enough to reach damper soil (some gnaphosids and lycosids): Weeds beneath the corn plants should create an even more humid microhabitat beneath them; the moisture loving linyphiids frequently used this habitat.

Plant spacing, row orientation, fertilization and variety, also influence the degree to which the developing canopy moderates the understory microclimate. Rows oriented east and west allowed more sunshine to reach the soil in the furrow than did rows oriented north and south, thus drying the surface soil and debris. At Orange Heights, where the soil was very wet to begin with, the high planting density

heavily shaded the soil; spiders typically associated with pond edges (e.g. Pirata and Dolomedes) found the resulting habitat suitable.

Architecture. Three families of spiders, with abundant representatives in the corn field (Linyphiidae, Araneidae, and Theridiidae), require a structure upon which to suspend their webs. Not only must the geometry suit the design of the web, but the location of the appropriate geometry must also put the spider in a position to secure suitable prey and in a suitable microclimate. The use of habitats by these spiders has repeatedly been shown to be dependent on the architecture of potential web scaffolding supports (Cherrett 1964, Colebourn 1974, and Robinson 1981). Some spider's webs are rather flexible (e.g. Tetragnatha and Leucauge venusta) and thus can be supported by corn leaves which rattle with the wind. Other spiders require a more secure attachment, such as the much sturdier corn stalk. Still other web spiders also require a retreat within a rolled or curled leaf.

The geometry and arrangement of corn plants are dependent on a number of factors, such as row spacing and orientation, planting density, varietal traits, insect and weather related damage, and fertilization. Densely planted fields will, besides altering the microclimate, provide sturdy supports that are closer together. Modern varieties

of corn have been bred for more erect leaves, meaning that the angle between the stalk and the leaf is smaller (Jugenheimer 1976). Root damage and water logged soil may cause prop roots to grow from the base of the corn plant. The resulting cavities between these roots were heavily used by spiders (especially Linyphiidae, Theridiidae and Lycosidae). Whether these species can find suitable alternative sites should determine whether their ability to colonize the field is affected by the prop roots.

As a spider grows, it generally builds a larger and larger snare with a likewise increase in the required dimensions for the supports. Plants are not evenly spaced in the drill row, and so a range of web spans are possible and eventually the larger spiders, such as Neoscona arabesca and Argiope trifasciata build webs which span across the furrow.

Many spiders which do not erect snares, frequently must find a secure place to build a retreat, which may or may not be provided by the corn plant. One of the most important functions of such retreats is protection from spider-hunting wasps. A lack of suitable retreat sites appeared to be a factor limiting the number of Chiricanthium inclusum in the corn fields and may also have worked against Aysha velox and Metaphidippus galathea.

The availability of sites for webs and retreats can change with the corn's phenology. For example, spiders which do not rebuild their webs frequently, such as

Uloborus, must locate their webs so as to minimize damage by the wind (Eberhard 1971) and so may be excluded from the corn field until the canopy provides sufficient shelter. As another example, M. galathea first used the undersurface of a corn leaf for its retreat, but quickly moved to the corn silk when flowering began, then later abandoned this site as the dead silk rotted. On the maturing plants these jumping spiders made their retreats among the dried stamens on the tassel, while others abandoned the corn plants altogether making their homes on the emerging weeds. Also, as Chew (1961) proposes, some spiders may orient towards vegetation upon which their camouflage functions optimally so that microstructures (e.g. trichomes, coloration) of the plant become important.

Planting date. Since the bionomics and life histories of spiders are also functions of time it is obvious that planting date can have a considerable influence on species composition and relative abundance of spider communities inhabiting a crop. In the literature Boiteau (1984) and Buschman et al. (1984), for example, have reported the significant effects of planting date on the populations of arachnids and insects in crop fields.

The mechanisms for these effects are in some cases quite clear. Peucetia viridans, for example, disperses by ballooning up through 15 April so that corn fields planted

later in the season are largely unavailable for colonization by this species. In most cases, however, the effects are more complex, as those related to the phenology of adjacent vegetation or crop fields. Large numbers of spiders are associated with the new spring foliage of oaks, and later disperse from these trees as the leaves mature (see Chapter IV); the synchrony of this event with the attractiveness of the corn field will be dependent on the planting date.

Trophic Relationships

As proposed by Whitcomb (1973) spiders play four basic roles in a crop field ecosystem. First, they are predators of the primary consumers of the crop, some of which are economic pests. Second, spiders feed freely on other entomophagous arthropods, including other spiders. Third, spiders serve as food for insect predators such as Coccinellidae (Whitcomb 1973) and Chrysopidae (Plagens 1981). Finally, spiders compete with insect predators for prey, which at times can be limiting for both groups of predators.

Primary Consumers. An understanding of the dynamics, composition and quantity of primary consumers in the corn field is vital to understanding the structure and function of the spider community.

Nearly all prey consumed by the corn field spiders are dependent on herbivory of the corn plant. Two major

exceptions are detritivores which feed and reproduce on the plant residue from the previous season, and strays and colonizers immigrating from other crop fields and nearby vegetation. Detritivore populations are dependent on the type and amount of crop residue, strays and colonizers on the area of the field relative to the magnitude of the immigrations. Both prey sources could be very important in the establishment phase of spider community development. For instance Pietraszko and Clercq (1982) have shown that the addition of organic matter to the soil significantly increases spider populations, while Luczac (1979) has shown the importance of the first meal for first instar spiders, a stage that frequently arrives in the field by ballooning (see Chapter III).

Early colonizing herbivores are an important food base for the development of a higher predaceous potential later in the season (Gonzales and Wilson 1982). Among the first herbivores to establish themselves on the corn plants in northern Florida were Homoptera, primarily corn leaf aphids (Rhopalosiphum maidis), but also various species of leafhoppers. Most frequently, I found the alate, foundress aphids, surrounded by a dozen or less offspring, located on the leaf sheath usually on the lower third of the plant. Pardosa milvina was an important predator at this stage (see Table 2-4). Other species of lycosids have been shown to be effective biological control agents of aphids in European

grain crops (Chiverton 1982, Clercq and Pietraszko 1983) and of the brown plant hopper of rice in the Philippines and Japan (Kartohardjono and Heinrichs 1984). Horner (1972) found Metaphidippus galathea to be an effective predator of the greenbug (Aphididae) on sorghum. Occasionally large colonies of R. maidis developed, sometimes upon the developing tassel which is protected in the whorl. Large colonies of aphids were nearly always tended by ants, Solenopsis sp. or Camponotus floridanus.

The other early arriving herbivores were the Cicadellidae, or leafhoppers. Very few nymphs were ever found, which could be due either to corn being an unsuitable host for these species (Douglas et al. 1966) and/or to the effectiveness of the biological control exhibited by the spiders and other predaceous insects. Cicadellids were captured as prey by a number of spiders, both wandering hunters and web spinners. Although leafhoppers rarely cause damage to corn directly, they are known to transmit a number of important viral diseases (Douglas et al. 1966).

Closely following the arrival of the homopterans are the egg laying adults of the two major lepidopterous pests of Florida corn, Spodoptera frugiperda (Fall Army Worm) and Heliothis zea (Corn Ear Worm). The eggs of these moths are potential prey for spiders such as Chiricanthium inclusum, Metaphidippus galathea and Oxyopes salticus (McDaniel and

Table 2-4 -- continued

PREDATORS	PREY
<u>Eustala anastera</u> <u>Gea heptagon</u> <u>Leucauge venusta</u> <u>Mangora gibberosa</u> <u>Neoscona arabesca</u> <u>Peucetia viridans</u> <u>Lycosa lenta</u> <u>Pardosa milvina</u> <u>Chiricanthium</u> <u>inclusum</u> <u>Misumenops celer</u> <u>Hentzia palmerum</u> <u>Metaphidippus</u> <u>galathea</u>	<u>Nezara viridula</u> <u>Sitophilus sp.</u> <u>Rhopalosiphum</u> <u>maidis</u> Cicadellidae Cercopidae Thysanoptera Ottitidae Agromyzidae Elateridae Chrysomelidae Scarabaeidae Gryllidae Nitidulidae

Table 2-5. Spider predation on predaceous and accessory insects as observed in corn fields in Alachua County, Florida. Fewer than 5 observations (small dots) and more than 5 observations (large dots). Successfully repelled attack (dash).

PREDATORS	PREY
	<u>Orius insidiosus</u> <u>Geocoris punctipes</u> <u>Spanogonicus sp.</u> Tachinidae Dolichopodidae Carabidae <u>Doru taeniatum</u> Braconidae Ichneumonidae Chalcidoidea <u>Solenopsis spp.</u> <u>Camponotus floridana</u> <u>Conomyrma insana</u> Nematocera (Diptera) Collembola Psocoptera
<u>Uloborus glomosus</u>	
<u>Achaeranea globosa</u>	.
<u>Anelosimus studiosus</u>	•
<u>Latrodectus mactans</u>	•
<u>Theridion flavonotatum</u>	•
<u>Theridion pictipes</u>	•
<u>Theridula opulenta</u>	•
<u>Eperigone banksi</u>	•
<u>Frontinella</u>	•
<u>pyramitella</u>	•
<u>Grammonota texana</u>	•
<u>Argiope trifasciata</u>	•
<u>Araneus pegnia</u>	•
<u>Cyclosa turbinata</u>	•
<u>Eriophora ravilla</u>	•

Sterling 1979, 1982) although I did not observe any egg predation. The oviposition by these two Lepidoptera differ markedly. S. frugiperda deposits masses of several hundred eggs and covers them with setae; hatching larvae disperse over a wide area and find suitable feeding sites in the whorl or developing ears. H. zea, on the other hand, deposits eggs singly at the feeding sites, either in the whorl or the corn silk. Spiders which hunt in the whorl or on the corn silk should be in a position to intercept eggs and larvae. The egg masses of S. frugiperda seem too widely dispersed for spider predation to be more than a rare, but possibly influential, event. Dispersing larvae should be more vulnerable to spider predation, however. Whitcomb (1967) recorded Oxyopes salticus and Grammonota texana as predators of H. zea larvae.

The only other significant group of herbivores, and thus prey for the developing spider community, were the leaf mining Diptera of the family Ottitidae. At times these flies were rather numerous and their damage was evident as broken leaves resulting from the larvae boring in the leaf midrib. Flying adult ottitids were vulnerable to sticky snares of araneids, and were also captured by hunting species like Metaphidippus galathea, Peucetia viridans and Misumenops.

This rather simple herbivore community changes abruptly with the onset of flowering. The copious production of

pollen by the tassels attracts numerous and varied pollen feeders including Hymenoptera, Thysanoptera, Diptera and Coleoptera. Insects which are generally classified as predators, such as Orius insidiosus also take to feeding on the abundant pollen (Dicke and Jarvis 1962). In addition, oviposition by the two principal Lepidoptera species increases, and the larvae of Nolidae and Geometridae also appear on the tassels and occasionally the corn silks.

Despite the numerous pollen feeders, much of the pollen falls to the ground or is caught among the plants' trichomes or in the leaf axils. Here Psocoptera, Collembola, and Dermaptera (among others) feed on the pollen and/or on the molds that grow on it, thereby producing great numbers of progeny. Many of these pollen feeding insects are taken as prey by spiders (see Table 2-5), however the sudden over abundance of prey simply overwhelms the spider community. Most of these pollen feeders are of little or no interest economically, but I believe that they divert the predatory activity of spiders (and other predators as well) away from the real pests, namely S. frugiperda and H. zea. The fact that the larvae of these pests are vulnerable to predation for only a relatively short period before they bore into the corn ear (Loke et al. 1983), accentuates the effect of the abundance of alternative prey.

In addition to the abundant prey developing on the pollen, the pentatomid pests, Nezara viridula and Euschistus

spp. begin ovipositing their eggs on the corn plants where the nymphs feed on the developing ears. Despite the frequent abundance of these pentatomids, I recorded just three incidents of predation on them by spiders. Ragsdale et al. (1981), using immunoassay techniques, recorded N. viridula nymphs as prey for Oxyopes salticus, Phidippus audax and Neoscona arabesca.

This abundance of prey in corn fields at the time of flowering may have been responsible for the negative effect that strip-cropping of corn with cotton had on the predaceous arthropods in cotton as observed by Burleigh et al. (1973).

With the advent of maturity, the damage done to the ears by Spodoptera and Heliothis draws saprophagous Diptera that feed and oviposit in the decaying frass, while the damaged kernels allow the entry of grain feeding Coleoptera (e.g. Sitophilus and Oryzaephilus) and ants (Solenopsis invicta). The adult Diptera were captured by many web building spiders as well as the vagrant hunters. Metaphidippus galathea was observed feeding on maggots that it extracted from the frass. The beetles were frequently captured in the stronger silken webs of Neoscona arabesca, Eriophora ravilla, Araneus pegnia, and Cyclosa turbinata or at the corn silk by Peucetia viridans. Also, as maturity progresses the dried stamens from the tassels fall to the ground and the lower leaves senesce, thus providing

additional food for the populations of Psocoptera and Collembola. By this time the spider community has reached its peak density and diversity, but soon begins to decline as the remainder of the plants senesce and the herbivores deplete their food supplies.

As a spider grows its prey requirements also change. Collembola and tiny Diptera which were necessary for the survival of first instar spiderlings may fail to even elicit a response by the older spiders. Thus the environment must provide an array of prey sizes in order for a spider to complete an entire generation within the field. This phenomenon may also limit the ability of a spider species to show a significant numerical response to a single prey species. After a bout of feeding, the spiders molt or produce offspring which can no longer use the same prey species. Thus, as proposed by Riechert and Lockley (1984), a diverse community of spiders should be better able to exert effective biological control of a single pest species.

Relationship of spiders with other predators. The trophic relationships that spiders have with other predators, as mentioned previously, consist of predation, competition, and as a source of prey for other predators.

Spiders are generally not very discriminating with regards to their choice of prey; any insect (or spider)

which a spider encounters that it can handle will become prey (Table 2-5). Prey preference tends to occur partly result of the degree of overlap in habitat preference. Orius spp., important predators of thrips and Lepidoptera eggs, were frequently taken as prey by hunting spiders, particularly in the vicinity of the corn silk by Metaphidippus, Misumenops and Peucetia. The greatest number of insect predators (including parasitoids) are taken as winged adults by the three families of web spinners (Araneidae, Linyphiidae and Theridiidae). This includes lebiine carabids, Orius, Geocoris, and dolichopodids, but especially the numerous hymenopterous parasitoids. There are parasitoids associated with essentially every one of the corn feeding herbivores discussed previously, but the greatest number are associated with the Rhopalosiphum maidis colonies. Large colonies of aphids attract a large and diverse association of predators together with their associated parasites. Spiders, again particularly the web spinners, in the vicinity of these colonies captured many of them. Unfortunately my sampling design was not such that I could detect a concentration of spiders in the vicinity of large aphid colonies.

Important parasitoids and predators of the major pests are certainly among the prey taken by spiders (Table 2-5). Thus some spiders, particularly the web spinners which take large numbers of winged Hymenoptera, may actually increase

the survival of, and level of damage produced by, Spodoptera frugiperda and Heliothis zea.

Ants are frequently abundant and important predators in agricultural fields (Whitcomb 1973). Achaeearanea globosa, among the most common spiders in the corn fields I studied, preys heavily on ants as do a number of other spiders (Table 2-5). Whether these spiders have a significant impact on populations of ants is not known. Besides direct predation, the webs of these spiders, which often act as "road blocks" where the plant stem meets the ground, could conceivably impede the foraging activity of the ants. Another of the common to abundant spiders in the corn field, Eperigone banksi, was also frequently recorded preying on ants.

Competition has long been thought to be a major force in structuring communities of organisms (e.g. Bowers and Brown 1982). But as Lewin (1983a, 1983b) discusses, the theory has come under heavy fire from those who contend that competition is only rarely of importance and can rarely be shown to have measurable effects. Strong (1982), for instance, feels that other forces, including predation and stochastic events, are the principal structuring forces in some communities. Despite a high degree of prey type overlap and similar habitat, Riechert and Cady (1983) failed to detect competitive release in a community of cliff-face dwelling spiders. Considering the great number of factors I have discussed so far, it seems that effects of competition

would be difficult to detect above all the "noise". Since prey in crop fields is at times quite limited early in the season (Price 1976), competition for limited resources might be more important then, than later in the season when there is an abundance of potential prey.

Riechert and Lockley (1984) hypothesize that intra-specific competition in the form of territoriality or other self limiting mechanisms (such as cannibalism) may be more important among spiders than interspecific competition. Although competition between spiders and predators may at times be significant, the design of the present study permits only a limited discussion. I observed two lines of evidence that suggested competition was involved. First, the abundant Pardosa milvina had a regular distribution (a significant departure from random, $p < 0.10$) in 2 of 8 sample sets. Regular distributions can be produced as a result of territorial exclusion. Second, in 1982, a significantly greater portion of the Pardosa milvina were found hunting on the corn plants in field AR-82A than in field AR-82B. And since the numbers of web spinners, particularly theridiids, were more abundant in AR-82B, I hypothesize that the web spinners were excluding the Pardosa milvina from the corn plant. P. milvina were noted as prey of the theridiids, a possible mechanism for this exclusion.

Generalist insect predators are frequently no less particular than spiders as to their choice of prey. It is

not surprising then that they will take spiders if the opportunity arises. Whitcomb et al. (1973) reported chrysopid larvae and coccinelid adults feeding on spiders and/or their eggs, while Dennison and Hodkinson (1983) reported spiders as a major component of the diet of Carabidae. Besides the generalist predators which occasionally take spiders, there are quite a number of predaceous and parasitic insects which specialize on spiders. The most important order of these are the Hymenoptera, including the Pompilidae, Sphecidae subfamily Trypoxyloninae (Krombein 1967) and Ichneumonidae (Eason et al. 1967). These spider predators were commonly seen hunting in the Archer and Gainesville corn fields.

Among the most frequent predators of spiders are other spiders. Besides those that take spiders opportunistically there are those that specialize on other spiders; Mimetus was relatively common in all the fields.

Vertebrate predators have long been neglected as important components of the predator community. This may be partly due to their prevalence only in smaller fields that have a greater area of undisturbed habitat nearby. I observed the southern toad (Bufo terrestris) repeatedly taking Pardosa spp. including females carrying eggs. Remains of spiders were found in the numerous droppings of armadillos (Dasypus novemcinctus) which forage in the fields at night. Lizards (Anolis carolinensis) and green tree

frogs (Hyla cinerea) were found in the corn fields hunting on the plants. Evidence of moles and shrews was found in the fields. Spiders form a large part of the diet of the voracious shrews (French 1984) and insectivorous birds (Kaczmareck et al. 1981).

Conclusion

The trophic relationships involving spiders in the corn field are thus seen to be exceedingly complex and to affect nearly every possible juncture in the food web, either directly or indirectly. Of concern to the economic entomologist is not so much the mere existence of these relationships, but their magnitude, and their resulting effects on the key pests and the final yield of the crop. Given the complexity and dynamic nature of the system it would be impractical, if not impossible, to determine all the magnitudes. Thus it seems reasonable to have a preliminary, in depth study of all the spiders inhabiting the corn field with an eye for anything that can give some insight as to which relationships, potentially, could have the most impact on the dynamics of the key pests. Any sort of mass collection technique (sweep net, suction trap, beating cloth) can not allow for a precise description of the microhabitats and predatory relationships of the individual species. The whole plant examination method allows for both quantitative estimates of intensity and density together with the

biological information necessary to make useful judgments with regards to future research.

But because most spiders are long lived and require a habitat with more stability than the annually cultivated and harvested field, a complete understanding of the biology of crop spiders requires an examination of their movement to and from adjacent habitats, the habitat associations of the principal species, and an investigation as to how they survive the winter in the crop field ecosystem (Mansour et al. 1983).

CHAPTER III
AERIAL DISPERSAL BY SPIDERS IN THE CORN FIELD ECOSYSTEM

Introduction

A recently planted agricultural field often presents a hostile environment for arthropods. The soil has probably been treated with insecticide, weeds are largely eliminated by herbicides and cultivators, and the plant debris from the past crop is buried deep. But soon after the emergence of the seedlings, winged herbivores arrive to deposit their eggs, which rapidly produce destructive colonies if they are not checked by colonizing predators.

One of the first groups of colonizing predators, spiders, differ from the majority of the other colonizers in that they arrive not as winged, egg laying adults, but most frequently as juveniles carried in the wind on silk from their spinnerets, the trademark of spiders' success. This has given spiders a great deal of flexibility in the structure of their life histories, and thus their potential for colonizing disturbed habitats such as agricultural fields. Whether a particular spider can successfully colonize a field will depend on a number of factors, such as its

microclimatic requirements, the structural requirements for the placement of its web or retreat, the occurrence of suitable prey (Luczac 1979), the chance of itself falling prey to one of many spider predators or diseases (e.g. Eason et al. 1967, Whitcomb 1973, Rau 1935), the toxicity of residual pesticides and the synchronization of the spider's dispersal and its requirements.

Past work on ballooning spiders includes Duffy (1956), a study of the aerial dispersal of spiders in a known community of British grassland spiders. Horner (1975) examined the phenology of ballooning salticidae in Oklahoma, Salmon and Horner (1977) the families of ballooning spiders in north central Texas, while the work of Yeargan (1975) is the only major work concerning the ballooning of spiders in an agricultural setting. His work identified the relationship between various physical factors and the daily ballooning activity of spiders caught over a California alfalfa field. The purpose of this study was to determine the composition of the aeronaut fauna and to gain information about the phenology of spider movement over an agricultural ecosystem, specifically a field corn system.

Site Descriptions

Three study sites in Alachua Co., Florida, were used during the study, all of which were planted to corn in

mid- to late March and harvested in July or August. At most sites, traps were operated during the off season as well, but with less intensity. The study period was from January 1983 to July 1984. The Archer site sat on a deep layer of Candler Fine Sand (USDA 1980) that supported xeric hammock or turkey oak scrub on less disturbed sites. Irrigated fields were rotated with peanuts, corn, watermelons and forage grasses. Cattle and some hogs were an integral part of this operation, often put in the field after harvest.

The Gainesville site sits on Norfolk Loamy Fine Sand, that supported southern mixed deciduous forest in nearby undisturbed sites. These non-irrigated fields were planted to corn most years and were occasionally double cropped with a winter hay or late season sorghum. No cattle were kept in the area, with all the crop being marketed.

Orange Heights presented a much different habitat. The mucky Mulat Sand of this site was poorly drained and water logged for extended periods of time. The 25 ha. field was surrounded by slash pine plantation, with the understory of the younger stands used for cattle. At the field center was a pond containing the remnants of a bald cypress dome. The summer crop is rotated between corn and soybeans; winter vegetables are grown as a second crop.

Methods and Materials

Sticky wire traps were used to capture ballooning spiders from over the fields. The design (Figure 3-1), modified from Duffy (1956) and suggestions from Greenstone (personal communication), consists of an upright furring strip (2.4 m) and a top cross piece (1.5 m) that supports a fine steel wire 1.2 m in length. The wire is coated with Tack Trap, (Animal Repellents Inc., Griffin, Ga.) a sticky polymer of isobutylene, for 1.0 m of its length.

A spider ballooning in the air clings to a long thread of silk. Should any portion of that length become stuck to the wire, the spider will climb the silk until reaching the sticky wire where it will be caught. A band of Tack Trap on the upright prevents spiders from crawling up from the ground.

Two to four traps were operated at each field and were serviced at 7 to 14 day intervals by carefully examining the wire for adhering spiders, teasing them from the Tack Trap with fine twigs or pine needles and placing them in mineral spirits. Once the sticky material had been removed, the specimens were transferred to 70% isopropyl alcohol for identification and storage. A new coating of Tack Trap would then be applied. Table 3-1 lists the field sites and the number of trap-days accumulated for each site and month.

Voucher specimens are deposited in the Florida State Collection of Arthropods.

Figure 3-1. Trap used for studying aerial dispersal in spiders. Upright consists of a furring strip (5 cm X 12 cm X 2 m), cross bar of pine molding (10 mm X 10 mm X 1.2 m).

TABLE 3-1. Sticky wire trap-days by month at four sites in Alachua County, Florida.

	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Archer, 1983	40	60	102	72	108	92	64	-	52	51	-	48
Archer, 1984	81	72	27	75	93	105	24	-	-	-	-	-
Gainesville, 1984	-	-	-	57	102	87	39	-	-	-	-	-
Orange Heights, 1983	78 ¹	-	-	-	76	85	54	-	75	105	69	57
TOTAL	199	132	129	204	379	169	181	-	127	166	69	105

1. January 1984. Traps at Orange Heights were operated from May 1983 through January 1984.

Results

During the 18 month study period, a total of 1,805 spiders, representing 15 families and at least 53 species, were captured. The families Araneidae (orb weavers) and Linyphiidae (sheet web weavers) had the largest portions of both species and numbers, but several other families made sizable contributions to the total. Figure 3-2 shows the proportions of the total capture that belonged to the major spider families.

On a seasonal basis, the intensity of ballooning activity, as indicated by Figures 3-3 and 3-4, ranged from a low of 3.7 spiders per 10 trap days during March 1984 at Archer, to a high of nearly 15 per 10 trap days at the same Archer field during April 1983. This indicates great fluctuation in activity from year to year. The great peak of Linyphiidae during April of 1983 was due especially to a single species, Erigone autumnalis, that occurred with low frequency the following year. Also, both the Lycosidae (primarily Pardosa milvina) and the Oxyopidae (lynx spiders, mostly Peucetia viridans) were also noticeably absent from the 1984 captures. Even still, the intensity of ballooning on a seasonal basis was relatively constant, at least for Archer 1983. Again, the Linyphiidae and Araneidae are well represented in the captures throughout the year, but as with

Figure 3-2. Family proportions of ballooning spiders captured from January, 1983 through July, 1984 in Alachua County, Florida using sticky wire traps.

Figure 3-3. Ballooning intensity of spiders by month at Archer, Florida during 1983 (A) and 1984 (B) as indicated by sticky wire traps.

Figure 3-4. Ballooning intensity of spiders by month in Alachua County, Florida at Orange Heights, during 1983 (A) and Gainesville (B), during 1984.

most of the other families, the species makeup changed considerably during the season.

Table 3-2 lists the identified species caught on the sticky wire traps, giving their seasonal phenology, relative frequency and an indication as to whether juveniles, adults, or both were represented. The age at which the species disperse by ballooning varies considerably. Peucetia viridans for example ballooned only as first instar spiderlings (defined here as the period following emergence from the egg sac and the next molt). This period extended from November until early April and represents the over wintering stage of this spider. Aysha spp. on the other hand ballooned throughout the year as first through third instars or occasionally as larger individuals, with seasonal variation not very pronounced. Like Aysha, first to third or fourth instars of Pardosa milvina balloon with high frequency, but mostly during October through March. Only an occasional specimen was caught on the traps during the summer months even though abundant juveniles were present in the fields (see Chapter II).

The majority of the Linyphiidae and many Theridion spp. captured were adults or penultimate adults. These spiders are mostly very small, averaging less than 2 mm in length. However, adult specimens of at least 25 other species were encountered, some as long as 5 mm.

TABLE 3-2. List, seasonal phenology and relative frequency of ballooning spiders captured on sticky wire traps in Alachua Co., Florida. * = Adult specimens captured. + = Infrequently captured. ++ = Commonly captured. +++ = Abundantly captured.

	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DICTYNIDAE												
* <u>Dictyna</u> sp.	+			*								
ULOBORIDAE												
* <u>Uloborus</u> <u>glomosus</u>				+		+	*					
THERIDIIDAE												
<u>Achaeranea</u> <u>globosa</u>								+			+	
* <u>A. porteri</u>						*						
<u>Anelosimus</u> <u>studiosus</u>	+						*				+	
* <u>Argyrodes</u> <u>fictitium</u>						+						
<u>Argyrodes</u> sp.												
* <u>Steotoda</u> quadrimaculata									*		+	
<u>Latrodectus</u> <u>mactans</u>								+				
<u>Spintharis</u> <u>flavidus</u>						+						+
* <u>Theridion</u> <u>crispulum</u>	+	+	+		*		+			+		
* <u>Theridion</u> spp.	+	+	++	+	+++	++	+	++	++	+++	+++	+

TABLES 3-2 -- continued

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LINYPHIIDAE												
* <u>Ceraticellus similis</u>	*	**	***	**	*	**	**		*	**	*	*
* <u>Ceratinops crenatus</u>					*							
* <u>Erigone autumnalis</u>	*	*	***	***	*	*				*	*	*
* <u>Florinda coccinea</u>	*			*	*	*				*	*	
ARANEIDAE												
<u>Araneus pegnia</u>	+	+	+	+	+	+		+		+	+	
* <u>Gea heptagon</u>	+				*	+				+	+	+
<u>Leucauge venusta</u>	+	+			+	+	+				+	
<u>Mangora gibberosa</u>			+	+	+		+					
<u>M. spiculata</u>	+	+	+	+						+		+
* <u>Mastophora bisaccata</u>												*
<u>Microthenea sagittata</u>				+								
<u>Neoscona sp.</u>												
<u>prob. arabesca</u>		++	++	++	+	+	+			+		+
<u>Tetragnatha sp.</u>												
<u>mostly laboriosa</u>	+	++	+	+	++	++	++	+	+	+	+	++
<u>Verrucosa arrenata</u>				+								

TABLES 3-2 -- continued

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MIMETIDAE												
<u>*Mimetes</u> sp.	+	*				++	+		+	+		
PISAURIDAE												
<u>Dolomedes</u> sp.	+		+									
<u>Pisaurina undulatus</u>	+											
<u>Pisaurina</u> sp.	+		+	+	+	+	+		+			+
LYCOSIDAE												
<u>Allocosa</u> sp.						+						
<u>Lycosa</u> sp.												
<u>prob. lenta</u>		+	+	+	+				+			
<u>Pardosa georgae</u>	+				+	+			+			+
<u>Pardosa</u> spp.												
<u>mostly milvina</u>	+++	+++	+++	+	+	+	+		++	+++	+	
<u>Pardosa saxatilis</u>				+					+	+		++
<u>Pirata</u> sp.	+++	+										
OXYOPTIDAE												
<u>Hamataliwa</u> sp.									+			
<u>Oxyopes</u> sp.												
<u>mostly salticus</u>		+	+	+	+		+	+	+	+		+
<u>Peucetia viridans</u>	++	+++	+++	++							+	+++

TABLE 3-2 -- continued

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GNAPHOSIDAE												
<u>Herpyllus</u> sp.				+		+						
<u>Poecilochroa</u> sp.							+					
CLUBIONIDAE												
<u>Chiricanthium</u>												
<u>inclusum</u>	+			+	+	+	++	++	++	+	+	+
* <u>Clubiona abbotti</u>					+							*
* <u>Clubiona procteri</u>												
<u>Clubiona</u> spp.												
<u>esp. abbotti</u>	+	+	++	++	+++	+++	+++	+++	+	+++	+	++
<u>Micaria</u> sp.							+					
<u>Scotinella</u> sp.					+							
<u>Trachelus</u> spp.												
<u>deceptus</u> &	+	+		+	+	+	+			+		++
ANYPHAENIDAE												
<u>Aysha</u> spp.	+	++	+	+	+++	+++	++	++	++	++	+	+++
THOMISIDAE												
<u>Misumenoides</u>												
<u>formosipes</u>	+		+	+			+					
<u>Misumenops</u> <u>celer</u>	+	+	+	+	+	++	+	+	+	+	+	+
<u>M. oblongus</u>				+		+	+				+	
<u>Tmarus</u> <u>angularis</u>												
<u>Xysticus</u> spp.					+	++	++	++	++	+		+

TABLES 3-2 -- continued

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PHILODROMIDAE												
* <u>Philodromus floridanus</u>	*											
* <u>Philodromus spp.</u>	+	+	++	+	+	+	+			+		++
SALTICIDAE												
<u>Corythalia canosa</u>							+		+			
<u>Habronatus sp.</u>					+							
* <u>Hentzia palmerum</u>	+	++	+	+	+	+	+	++	++	++	++	++
* <u>Marpissa sp.</u>												*
<u>Metaphidippus</u>												
<u>galathea</u>	+		++	+	+	+	+				+	+
* <u>peckhamia</u>												
<u>americana</u>				*			+					
<u>Phidippus spp.</u>					+		+					+
<u>Thiodina sp.</u>	+				+	+	+			+		
* <u>Zygoballus</u>												
<u>sexpunctatus</u>					*							

The frequency distribution of spider size classes, as expressed by the total body length, is presented in Figure 3-5. The size class 1.0-1.5 mm contains 44% of all the spiders captured. The next smaller size class, 0.5-1.0 mm, had considerably fewer spiders, while no spiders smaller than 0.5 mm were captured. An apparent logarithmic decrease in numbers of spiders captured occurs for 0.5 mm increments above 1.5 mm. Clausen (1983) showed that a linear relation exists between the natural logarithm of the wet weight and the natural logarithm of the length. Since weight is a major component in the ability of a spider to balloon this may explain the shape of the weight length distribution.

During the course of the study observations of ballooning spiders taking to the air were made. The usual technique used by ballooning spiders, as described in the literature (Bristowe 1929, Blackwall 1827, and Richter 1970), is for the spider to hold the spinnerets, which are at the posterior of the abdomen, as high off the substrate and into the wind as possible. Once a strand of silk, long enough to carry the spider upwards has been drawn out into the wind, the spider releases hold of the substrate. I observed this in Peucetia viridans. However, I observed quite a different method in first instar Misumenops and Hentzia, which began by hanging from a projecting leaf or branch. When a breeze was produced, the spider was carried upwards, much as a kite, while the drag line remained

Figure 3-5. Frequency distribution of size classes of ballooning spiders captured on sticky wire traps in Alachua County, Florida from January, 1983 through July, 1984.

attached to the take off point as would a kite string. In some cases the silk eventually became detached from substrate while other times a break occurred nearer the spider leaving an empty strand of silk attached to the take-off point while the spider was carried away in the wind. Coyle (1985) described a very similar ballooning behavior in the mygalomorph spider, Ummidia. A method similar to this was also observed in slightly larger spiders moving between plants without becoming totally airborne. This behavior could be related to the hanging defense of diurnal wandering spiders, where spiders gain protection from nocturnal predators by remaining motionless while hanging by a strand of silk at night (Carroll 1977).

Discussion

Crop fields as a habitat for arthropods are unpredictable (as defined by Colwell 1974) because biotic and abiotic conditions (e.g. carrying capacity) change rapidly on a time sequence that is frequently neither constant nor contingent. Greenstone (1982), using two species of Pardosa, empirically demonstrated a relationship between a species' habitat predictability and its tendency to balloon. Thus it is not surprising that many of the major components of crop spider communities in the southeastern United States (Whitcomb et al. 1963, Dean et al. 1982, Culin and Yeargan

1983a) were captured with high frequency on the ballooning traps.

If age structure and phenology are considered, five general categories of dispersal behavior were observed during the present study: (1) one synchronous generation per year, with only one or two instars ballooning; Peucetia viridans and Pirata sp. were the most common examples of this type; (2) one synchronous generation per year, but with several instars dispersing by air; examples are Neoscona arabesca and Lycosa lenta; (3) overlapping generations with several instars ballooning, primarily during a short part of the year; Pardosa milvina is the principal species in this category; (4) overlapping generations, with only one or two instars ballooning throughout the year; this strategy is used primarily by the smaller species of Linyphiidae and Theridion, where adults and penultimate adults are the stages which balloon; (5) overlapping generations with several instars ballooning throughout the year. Many of the most abundant spiders of crops in northern Florida adopt this dispersal strategy such as Misumenops celer, Chiricanthium inclusum, Aysha velox, Metaphidippus galathea, Hentzia palmerum, Oxyopes salticus and Tetragnatha laboriosa.

That this last strategy is used widely by crop spiders is evidence that it is an adaptation for colonization of environments that are unpredictable over space and time. These captures do not simply represent local movement of

abundant spiders in the corn fields over which the traps were operated. Oxyopes salticus, Misumenoides formosipes, and Aysha velox, for example, are abundant in other crops (Neal 1974 and Lockley et al., 1979) but not in corn fields (see Chapter 2). For species which exploit a habitat with a carrying capacity that is variable with time (characteristic of crop fields) the best strategy is for the population to maintain a relatively high magnitude of dispersal at all density levels (Gadgil 1971).

Seasonal, yearly and local fluctuations in ballooning captures of a given species can be a function of a number of factors which modify the evolved migratory behavior. Most obvious of these is a change in the population density due to predation, weather-related mortality, pesticides, or a change in the carrying capacity of the environment. I was able to identify some of these during the course of the study. The great number of Erigone autumnalis captured in April 1983 was coming from a nearby (.8 km) field of maturing rye. A burst of Misumenops celer was observed just after tasseling was complete, and another burst of M. celer and other species as the whole crop was mature and drying. Pardosa milvina ballooners were more frequently encountered on traps located near areas which were heavily grazed by cattle, since these areas are frequently heavily populated by these spiders (see Chapter IV). Other species balloon with the phenological changes in the surrounding trees and

weeds. Land use and management practices are the major driving force behind much of these changes and offer possibilities for altering the composition of the species pool from which a crop field will be colonized.

Thus, differences in the pool of ballooning species (and thus the pool of potential corn field colonists) between the three sample sites was evident as shown in Table 3-3. These differences were primarily in the relative intensities of principal species rather than differences in the species lists. For the most part, these differences reflected the differences in the dominance structure of the spider communities occurring on the weeds and adjacent vegetation (see chapter IV). This indicates that most ballooning spiders move only a short distance from their source, but that a small portion may be carried to more distant points. This is consistent with Price (1975) who states that it is mostly maladaptive to disperse more than locally; an individual has only a small chance of finding a suitable distant source.

Weather, the main force not under the control of man, was responsible for frequent alterations in ballooning intensity. One such weather phenomenon, a severe freeze in December of 1983, was probably responsible for the near absence of some species in the spring of 1984. Also, as similarly recorded by Yeargan (1975) and Glick (1939), during the winter months, clear, warm, balmy days produced

Table 3-3. Relative ballooning frequencies for spiders at three sites in Alachua County, Florida.

Spider	Archer	Orange Heights	Gainesville
<u>Theridion</u> spp.	+++	++	++
<u>Ceraticellus similis</u>	+++	++	+
<u>Erigone autumnalis</u>	++	+	+
<u>Florinda coccinea</u>	++	+	-
<u>Araneus pegnia</u>	++	+	+
<u>Gea heptagon</u>	+	++	-
<u>Leucauge venusta</u>	++	++	-
<u>Mangora</u> spp.	++	+	+
<u>Neoscona arabesca</u>	+++	+	++
<u>Tetragnatha laboriosa</u>	+++	++	++
<u>Mimetus</u> sp.	++	+	+
<u>Pisaurina</u> cf. <u>mira</u>	+	+	
<u>Pardosa milvina</u>	+++	++	++
<u>Lycosa</u> cf. <u>lenta</u>	++	-	-
<u>Oxyopes salticus</u>	+	++	+
<u>Peucetia viridans</u>	+++	+	+
<u>Chiricanthium inclusum</u>	+++	+	++
<u>Clubiona</u> spp.	+++	++	++
<u>Aysa</u> spp.	+++	++	++
<u>Misumenoides formosipes</u>	+	+	-
<u>Misumenops celer</u>	++	+	++
<u>Xysticus</u> spp.	++	+	+
<u>Philodromus</u> spp.	++	+	++
<u>Hentzia palmerum</u>	++	+++	++
<u>Metaphidippus galathea</u>	++	+	+
<u>Phidippus</u> spp.	+	+	+
<u>Thiodina sylvana</u>	+	++	-

the greatest numbers of ballooning spiders. However, the largest species, such as Lycosa lenta were captured only during rather windy weather. Drought and irrigation practices can work in concert to affect the movement of spiders. Under drought conditions spiders exited unirrigated fields and accumulated in tree-shaded areas of the field or on deep-rooted plants that still supported insect prey. The mild winters in north Florida were partly responsible for relatively constant ballooning activity year round, which is in contrast to results of studies in more temperate areas (Horner 1975, Duffy 1956).

The males of at least 25 species (other than Linyphiidae) were captured on the sticky wire traps, suggesting that ballooning is an effective means to search for females. The morphology of male spiders may aid them in this mode of locomotion: generally small body size with long setaceous legs. Just as the pappus of a composite seed provides resistance to the movement of air through it, which is transformed into aerial lift, so do the long legs and setae provide aerial lift to the spider when air currents move through them. The long legs and setae should especially aid spiders that become airborne in the fashion of Misumenops and Hentzia described above.

Mimetus is a genus of spiders in which all stages possess long legs and setae. These structures are generally agreed to serve the spider in capturing its usual prey,

the webs of prospective prey, as evidenced by their propensity for ballooning (see Table 3-2). Argyrodes fictitium, another spider with long spindly legs that preys on other spiders (Trail 1980), was also captured during this study. Interestingly, other species of Argyrodes, which are primarily kleptoparasites, are not long legged and were rarely caught ballooning despite their abundance in the areas near the fields. As kleptoparasites, their need to move from one host's web to another is diminished. Finally, spiders of the genus Tetragnatha are among the greatest aeronauts. Numerous middle instars as large as 3.5mm were captured, while Okuma (1981) recorded their arrival on buoys 200 km from land in the South China Sea. It may be that the long slender legs of these spiders, also aid in their dispersal by air.

Trapping schemes used to study biological phenomena are not without biases, and the sticky wire traps used in this study are no exception. Work by Greenstone (1985) has shown that sticky wire traps consistently underestimate the lightest spiders, particularly those weighing less than 0.4mg (based on Clausen's (1983) weight/length data these spiders are less than 1mm in length). Thus the numbers of juvenile Linyphiidae, Achaearanea, and Theridion ballooning in Alachua Co. may have been considerably greater than was indicated by the trapping scheme. Greenstone also found that trap height had significant effects on the composition

ballooning in Alachua Co. may have been considerably greater than was indicated by the trapping scheme. Greenstone et al. also found that trap height had significant effects on the composition of the aeronaut fauna collected. Thus a constant height of traps probably over- or underestimates certain species. However, the simple design of these traps and the ease of their operation should permit their use to greatly expand our knowledge of aerial dispersal in spiders, the role it plays in their life history strategies, and the role spiders play in both natural and agricultural ecosystems.

CHAPTER IV WEED ASSOCIATIONS OF SPIDERS IN THE CORN FIELD ECOSYSTEM

Introduction

From planting to harvest most row crops require only part of the year, and since many spiders' life cycles require a year or longer to complete (Gertsch 1979) it becomes obvious that a crop spider community must be an integral extension of communities occurring on nearby permanent vegetation (LeSar and Unzicker 1978). Further, because spiders possess excellent dispersal capabilities (see Chapter III), the community composition of the source habitats and the dynamic exchanges between systems become the central points in understanding the dynamics and structure of spider communities in crop fields.

Studies devoted to spiders associated with weeds in agricultural situations are limited. Stadlebacher and Lockley (1983) tallied the spiders occurring on Geranium distichum, a winter annual of southern Mississippi agricultural areas. Altieri and Whitcomb included spiders in their list of predators associated with Mexican Tea (Chenopodium ambrosioides) (1979) and Camphorweed (Heterotheca subaxillaris) (1980) in North Florida.

One of the most difficult aspects of dealing with crop or weed spider communities, is the sheer number of species, especially if one is unwilling to lump distinct biological species into convenient groups for the purpose of making statistical analyses. In addition, many of the most important species occurring in crop fields have asynchronous generations, so that any given population in the crop or in some adjacent habitat may consist of all instars from first through reproducing adults. And again, since the individual instars may have varying habitat and prey requirements, to treat them together as biological equivalents may lead to spurious conclusions.

Plants and weeds growing in a crop ecosystem possess a variety of growth phenologies, such as spring and summer annuals, herbaceous spring and summer perennials, or woody perennials such as shrubs and fence row trees. In addition, they vary in their assembly of primary and secondary consumers, structures for web scaffolding and retreats, and the microclimate of their preferred habitat. Each of these factors can contribute to the array of spiders associated with a given plant and the temporal component of the association.

Given this complexity of confounding variables, the purpose of this study was to identify the species composition of spiders occurring in association with the principal plants in a field corn ecosystem, to detect the

interplant movements of the most abundant species, and to obtain a general picture of which plants potentially act as sources, sinks, or intermediate stops for colonizing spiders.

Site Descriptions

Three study sites in Alachua Co., Florida, were used during the study, all of which were planted to corn in mid to late March and harvested in July or August. The Archer site sat on a deep layer of Candler Fine Sand (USDA 1980) that supported xeric hammock or turkey oak scrub on less disturbed sites. Irrigated fields were rotated with peanuts, corn, watermelons and forage grasses. Cattle and a few hogs were an integral part of this operation, often put in the fields after harvest.

The Gainesville site is located on a Norfolk Loamy Fine Sand that supported southern mixed hardwood forest (Monk 1965) in nearby undisturbed sites. These non-irrigated fields were planted to corn most years and were occasionally double cropped with a winter hay or late season sorghum. No cattle were kept in the area, with all the crop being marketed.

Orange Heights presented a much different habitat. The mucky Mulat Sand of this site was poorly drained and water logged for extended periods of time. The 25 ha. field was

surrounded by slash pine plantation, with the understory of the younger stands used for cattle. At the field center was a pond containing the remnants of a bald cypress dome. The summer crop is rotated between corn and soybeans; winter vegetables are grown as a second crop.

Methods and Materials

The predominant weed, shrub, and tree species growing in the vicinity of each field were sampled for spiders. This was conducted by selecting stems or branches that measured approximately 0.5 meters in length, carefully pruning them from the plant while holding a 45 cm diameter sweep net underneath, and then vigorously shaking the plant sample inside the net. This assured that a majority of the spiders would be dislodged and recovered in the bottom of the net. The spiders contained in the net bag were preserved in alcohol for later identification in the laboratory. For the most part, a sample consisted of 10 to 25 such plant stems; this sample size was determined by the abundance of spiders on the plant and the prevalence of the plant around the field. This "net-bag" sampling technique was impractical for grasses and thorny blackberry shrubs, where standard use of the 45-cm sweep net was substituted. Again the sample unit was 10 or 25 sweeps.

Chew (1961) and others (e.g. Jennings 1971, Duffy 1962) have noted the difficulty in comparing the spider communities between plant species because of the difficulty in equalizing the sample size. Despite the differing structures of individual plants this method gives a rough correspondence of total leaf area sampled from each species. Also, the actual process is slightly different for branches that grow vertically versus those that grow horizontally. Finally this sampling technique admittedly samples only foliage species and does not adequately sample species that occur on the lowest stems. Thus comparison of the weed spider communities with the corn field communities is restricted to species inhabiting the upper foliage layer.

All sampling was conducted in the morning hours to preclude any time dependent differences in spider activity and was conducted throughout the year but was more intense during the growing season. The most abundant plant species were sampled at weekly or biweekly intervals (when present) but less frequent species were sampled only as time permitted.

Spiders were identified according to Kaston (1981) and the individually published specific keys referenced in same. Juvenile spiders of many species could be identified by comparison with known specimens reared from adults in the laboratory or by association with adults. Closely similar species which co-occurred could not be separated as

juveniles. Voucher specimens are submitted at the Florida State Collection of Arthropods.

Results

During the three year period 4500 individual plant stems were sampled, yielding 3312 spiders. The data were analyzed in two principal ways. First the relative intensity of the major species of spider on the various plants was determined and is presented in Tables 4-1, 4-2, 4-3 and 4-4. By looking at the rows across the tables, it is clearly seen, that some plant species have much higher densities and diversities of spiders associated with them than do others, while the columns demonstrate that indeed there are specific associations between spiders and plants.

The second analysis was of the temporal dynamics of the six most common spiders and their association with plants in the corn field ecosystem. These results are shown in Figures 4-1 (Peucetia viridans), 4-2 (Misumenops celer), 4-3 (Aysha spp.), 4-4 (Chiricanthium inclusum), 4-5 (Hentzia palmerum) and 4-6 (Metaphidippus galathea). The width of the horizontal bars indicates the approximate relative intensity of the spider on the plant over time. Since the density of some plants (especially annuals) changed substantially during the season, the density of a spider per unit area is function a of both the spider's intensity and the plant's density.

Table 4-4. Association of spiders with weeds, shrubs and saplings growing in shaded areas adjacent to corn fields in Alachua County, Florida. Relative intensity indicated by open circles (less than 1 spider per 25 stems), small solid circles (1 to 5 spiders per 25 stems) and large solid circles (more than 5 spiders per 25 stems).

SAPLINGS & WEEDS	SPIDERS																													
		ARANEIDAE	THERIDIIDAE	LINYPHIIDAE	Tetragnathina	laboriosa	Mangora gibberosa	Neoscona arabesca	Eriophora ravilla	Theiridion spp.	Theridula opulenta	Pardosa milvina	Peucetia viridans	Oxyopes sp.	Chiricanthium	Incisusum	Cubiona sp.	Trachelus spp.	Ayscha spp.	Misumenops celer	Misumenoides	formosipes	Xysticus spp.	Philodromus spp.	Hentzia palmerum	Metaphidippus	galathea	Phidippus spp.	Thiodina sylvana	
<u>Callicarpa americana</u>		•					○					○	•							•	•	○		•	•	○	○	○	•	
<u>Celtis laevigata</u>		•		○																				○	•	○	○	○	○	
<u>Myrica cerifera</u>		•		○	○		○	○	•				•	○	○	○	○	○	○	•	•	•		•	•	•	•	•	•	
<u>Ilex glabra</u>		•														•									•	•	•	○	○	
<u>Phytolacca americana</u>		•		○			○	○					○			○		○	•	•	•		•	•	•	•	•	•	○	
<u>Solanum americanum</u>		•		•				○					•	•		○		○	•	•	•		•	•	•	•	•	•	○	
<u>Lepidium virginicum</u>		•		○					•				•			•			○	○	•							•	○	
<u>Hieracium gronovii</u>		○		○									•	•		•			○	○	•				•	•	•	•	○	

Figure 4-1. Temporal association of Peucetia viridans with plants in and near the field corn ecosystem in Alachua County, Florida. Width of horizontal bar indicates approximate relative intensity.

Figure 4-2. Temporal association of Misumenops celer with plants in and near the field corn ecosystem in Alachua County, Florida. Width of horizontal bar indicates approximate relative intensity.

Figure 4-3. Temporal association of Aysha velox with plants in and near the field corn ecosystem in Alachua County, Florida. Width of horizontal bar indicates approximate relative intensity.

Figure 4-4. Temporal association of Chiricanthium inclusum with plants in and near the field corn ecosystem in Alachua County, Florida. Width of horizontal bar indicates approximate relative intensity.

Figure 4-5. Temporal association of Hentzia palmerum with plants in and near the field corn ecosystem in Alachua County, Florida. Width of horizontal bar indicates approximate relative intensity.

Figure 4-6. Temporal association of Metaphidippus galathea with plants in and near the field corn ecosystem in Alachua County, Florida. Width of horizontal bar indicates approximate relative intensity.

Discussion

The density and diversity of spiders associated with a plant seemed to be most closely affected by the density and diversity of prey on the plant. The potential prey associated with Richardia scabra, for example, was largely limited to flower visitors, and so the spider fauna associated with this plant is rather meager as compared to Indigofera or Cassia. Again, the spider association on Quercus, particularly in the spring, parallels the great flurry of herbivores that feed on the developing leaves, while Liquidambar styraciflua has few spring time herbivores and thus few associated spiders.

The diversity, as both evenness and total number of species, was also affected by the sample size and the period of time over which the plant was present. Melilotus, Phytolacca, and Lepidium are late winter to early spring plants in northern Florida, and so smaller samples over a shorter period of time were taken. Spider density on these plants was relatively high (which again paralleled abundant prey) but was restricted to fewer species.

Specific associations offer many lines of conjecture as to possible reasons for them, however I shall present only those that were most clearly demonstrated by the sampling and general observations. Three major attributes of the plants that determined which spiders were associated with

them were the plant's architecture, the microclimate where the plant usually grows, and the array and relative benefits of potential prey that the plant attracts (Morse and Fritz 1982, Riechert 1973).

Structures for webs or retreats are important to many species of spiders (Duffy 1962, Cherrett 1964, Colebourn 1964, Robinson 1981). Araneidae were, for example, generally more abundant on the stiff, woody plants than on the herbaceous ones. The araneids which did occur on the herbaceous plants were largely nocturnal species which produce temporary webs so that damage by the wind would be minimized. Selection of web sites that minimize damage by the wind was demonstrated for Uloborus by Eberhard (1971). Theridiidae which generally suspend their webs from the lower surface of leaves such as Theridula and Theridion, were more common on plants with broad leaves than on those with finely dissected leaves. Finally, both families of sac spiders, Clubionidae and Anyphaenidae, were more common on the plants with finely dissected leaves, or broad leaves tattered by lepidoptera; these plants provided better sites for the silk retreats of these spiders.

Microclimatic conditions, especially humidity and light, have long been accepted as major factors in determining the distribution of spiders (Cloudsley-Thompson 1962). The four tables are arranged accordingly into sunny annual weeds, sunny perennial weeds, shaded herbs, shrubs

and saplings, and the major trees. The canopies of trees such as oaks are sun drenched and thus probably present a microclimate similar to the open field. This was evidenced by the similarity between the fauna of Quercus spp. with the sunny field weeds. There were a number of other associations that appeared to be dictated, at least in part, by the microclimate. Among the salticidae, Hentzia palmerum and Thiodina were more abundant than Metaphidippus galathea on partially shaded plants, while the opposite was true on plants in full sunlight. Also, among the similar Clubionidae and Anyphaenidae, Chiricanthium inclusum was more abundant on the sunny plants than Trachelas, Clubiona, and Aysa spp, again with the opposite true on shaded plants.

Microclimate may not be the direct or sole component governing these associations since Bigger (1981) and Futuyama and Gould (1979) have shown that the arthropod community as a whole is composed of different taxonomic groups between sunny and shaded vegetation; thus the relationships may also be related to differences in the types of available prey.

The lack of prey associated with certain plants (e.g. Richardia scabra) clearly inhibited associations of many spiders with those plants, however specific differences due to differences in prey types are difficult to detect without numerical data concerning the communities of potential prey. Misumenops celer and Peucetia viridans which prey heavily on

pollenators were strongly associated with plants in flower, particularly those with a densely clustered inflorescence. Louda (1982), also studying P. viridans, found them to hunt from the denser, flat topped clusters of Haplopappus spp.

The temporal association of the six most common spiders with plants in the corn field system provides potentially very useful information for understanding the life history of these spiders and for the development of management strategies. I shall discuss the dynamics for each of the six species illustrated. During these discussions it is important to know that following harvest of the corn crop, Indigofera and Cassia became very abundant and produced nearly 100% cover.

Peucetia viridans (Figure 4-1), with a single, synchronous generation, first occurred as large numbers of first instar spiderlings on the fresh new foliage of oaks (Quercus spp.) from which they moved (probably by ballooning) in early April to the corn field, Sida rhombifolia, Celtis and Solanum. Subsequent movements of P. viridans to Ambrosia, Sida, Cassia and Indigofera was probably by bridging and/or crawling. The intensity of P. viridans on most of the plants was low by September which may have been due in part to the absence of more preferred plants such as Monarda (bee balm) and Eupatorium (dog fennel) (Whitcomb 1984). The plants upon which these spiders could finally reproduce, i.e. Sida, Chenopodium, and Eupatorium are avoided by cattle

and so were frequently abundant in pastures. These plants were thus the likely sources for the first instar P. viridans the following season. The fate of those that stay on the Indigofera or Cassia is less certain; in the fall these weeds are either plowed under for mulch or used as forage for cattle.

The movements of the remaining species are more difficult to interpret because the spiders have widely overlapping generations. Thus a low population of reproducing adults on one plant may represent a source of colonizing juveniles while a high population of juveniles on another plant may represent temporary residents that will soon move to another plant. Misumenops celer for example were most abundant as early instars on Paspalum, middle juveniles on Ambrosia and later instars and adults on Cassia and Sida rhombifolia. Although direct movement between these plants was not observed, it seems the most likely explanation. Movements are probably a function of the changes in the prey on the weeds and the changing prey requirements of the growing spiders, but may also be related to changes in microclimate and light reactions (Cherrett 1964).

Aysha spp. occurred as reproducing adults only rarely on the weeds growing in the fields but rather on adjacent, semi-shaded trees and shrubs. Thus the adults on Quercus and Celtis represented the source of juveniles; some stayed on

the trees while others ballooned to the field weeds such as Sida, Ambrosia, and Cassia. The rarity of adults on these plants suggests that the spiders may return to the trees before maturing. Chiricanthium inclusum occurred sporadically as reproducing adults on shrubs, trees, and Sida, the offspring of which colonized the field corn and then the emerging legumes, Cassia and Indigofera; by the end of the season adults were found on these plants as well.

The two salticidae, Hentzia palmerum and Metaphidippus galathea, were abundant on many of the weeds and plants associated with the field corn ecosystem. They were also quite common on the corn plants. In the spring H. palmerum and especially M. galathea were common on the Quercus spp. This reflected a general trend throughout the season with M. galathea preferring the plants in full sunlight and H. palmerum having slightly lower intensities but less segregation between shade and sunlight plants. Like Misumenops celer, Aysha and Chiricanthium these spiders move frequently by ballooning (see Chapter III) in the early to middle instars. Adults are less likely to move far, so that plants that provide suitable habitat and prey for adults early in the season can act as sources of dispersing juveniles for the emerging corn crop and/or the weeds. Hence, for M. galathea, the sources of juveniles were the oak trees, and for H. palmerum, the sources were Sida rhombifolia, Phytolacca, and Callicarpa.

The frequent dispersal of juvenile spiders between plants and adjacent habitats (also Enders 1975) contrasts sharply with the strategy employed by most predaceous insects, which are mobile in the winged adult stage.

Manipulation of the weeds in and around crop fields offers the easiest way to manipulate the communities of spiders as well as many other predaceous insects in the crop field. Most of these manipulations are inadvertent and are merely a function of land use and farming practices. Grazing of cattle, for example, tends to favor Eupatorium, Rubus, Chenopodium ambrosioides, Asimina and therefore the spiders they support. Heavy grazing by cattle also tend to increase the numbers of Pardosa milvina. Barren patches of soil provide the preferred habitat for this cursorial species while the dung breeds dipterous prey. The cattle also carry water from the pond or well; the spiders subsequently extract this water from the dung. The range and movement of Pardosa from these cattle pastures could be in response to prey density (Hallander 1970) which would occur with the rotation of the cattle between pastures.

The trees growing near crop fields may be more important than previously recognized. Oaks especially have tremendous numbers of spiders associated with them. Importantly, many of these spiders migrate from the oaks in mid spring when the populations of oak feeding herbivores

decline as tannic acids begin to accumulate in the leaves (Wratten 1981). Many of these spiders (or their offspring) end up in the corn fields. Turner (1984) also recorded the abundance of spiders among arboreal predators.

Slash pine (Pinus elliotii) plantations offer few colonists for the corn field, but as must be considered when any plant is desired as a source of predators, there are few herbivores common to pines and most crops.

The perimeters of crop fields normally consist of mown grass and or weeds that allow for access and maneuvering of farm equipment. Although these areas are generally quite narrow in relation to the whole field, they receive fertilizers and irrigation water from the crop field, and so may be particularly productive. Movement of spiders into and out of these field borders are controlled by the changing phenologies and composition of the weed flora but also by the timing and frequency of mowing. Some of the spiders remain after mowing as they do in alfalfa (Culin and Yeargan 1983a, 1983b), but many move either to the corn plants or to adjacent habitat depending on which is more attractive at the time. If the corn field is just entering the silking stage, potential prey is also becoming abundant and thus the spiders should end up there.

Manipulation of weedy habitat is one alternative for manipulating predators (Altieri and Todd 1981), another is strip cropping. Strip cropping has appeal because the

predator source (which may have a dual function acting as a trap crop for pest species) has economic value in itself. Fye (1972) discussed the requirements of strip crops which are expected to be predator and parasite sources. These include a tolerant crop, the proper insect complex, timing, and mobility of the predators and parasites.

Besides being a source of spiders that can colonize a crop field, adjacent flora and within field weeds can also act as sinks for spiders that leave the crop at maturity. Given the potentially large numbers of spiders from the crop, it is probable that the spider fauna of the weeds is also intricately affected by the crop. If spiders are indeed beneficial components of the predaceous arthropods in crop fields, it is clear that a holistic view of the crop field ecosystem (LeSar and Unzicker 1978) and a complete understanding of the biology and ecology of the spider species (Mansour et al. 1983) are necessary in order to assess and manipulate the spider community effectively.

CHAPTER V
CORN STUBBLE AS AN OVERWINTERING SITE
FOR SPIDERS IN FLORIDA

Entomologists have learned to take advantage of the overwintering strategies used by herbivorous insects, such as the boll weevil (Slosser et al. 1984), the southwestern corn borer (Archer et al. 1983), and the bean leaf beetle (Jeffords et al. 1983). Overwintering populations can be limited by tilling, which exposes and breaks up the post harvest trash, and/or by removing accumulated leaf litter in the borders where the hibernating stages are found.

But studies concerning the overwintering stages and sites of predaceous arthropods found in agroecosystems have largely been neglected, particularly in the United States (Desender 1982). Thus our ability to manipulate populations of beneficial arthropods is hindered. Perhaps this is due in part to entomologists' desire to publish the previous summer's data during the winter months.

Spiders, due to their long life cycles, and slow rates of reproduction, should be particularly dependent on the adequacy of suitable overwintering sites. The purpose of this study was to elucidate the type and location of such sites in the field corn ecosystem.

Site Descriptions

Two corn fields in northern Florida were examined for overwintering spiders. The first was located near Archer, Florida in southwestern Alachua County and was studied during the winter of 1982/1983. The second field was located on the Tall Timbers Research Station in northern Leon County and was studied during the winter of 1983/1984. The Archer site sat on a deep layer of Candler Fine Sand (USDA 1980) that supported xeric hammock or turkey oak scrub on near by, less disturbed sites. Irrigated fields were rotated with peanuts, corn, watermelons and forage grasses. Cattle, and to a lesser extent hogs, were an integral part of this operation, often put in the field after harvest.

The Tall Timbers corn fields were planted on a sandy clay loam soil and were surrounded by fire managed slash pine plantation, that had been maintained with the dual purpose of maximizing wildlife populations, particularly quail and deer. The post harvest corn trash was thus left in the field for the birds and animals to glean.

Methods and Materials

The trash and leaf litter in the corn fields were examined and sifted over a white cloth. Spiders and insects were collected and preserved in alcohol. Once it was

established that spiders and insects were particularly abundant in the corn stubble itself, sets of 10 corn stalks and cobs were sampled from the corn fields, but could not be selected at random since the harvesters tend to distribute the debris so unevenly. A total of 400 corn stalks with ears were examined during the two winter seasons. The precise location of hidden, inactive spiders in the stubble was noted while the activity of spiders that were moving about or were in webs was also noted.

All sampling at both fields was conducted between 15 December and 15 February. Identification was accomplished by use of the keys in Kaston (1981) and by comparison with specimens in the Florida State Collection of Arthropods (F.S.C.A.). Voucher specimens of all species collected are deposited in the F.S.C.A.

Results

The corn stubble provided two basic hiding places for overwintering spiders. The leaf sheath normally remains attached to the corn stalk, where it overlays an indentation that runs the length of the stalk. A cross section of a corn stalk showing this protected cavity is shown in Figure 5-1; this was the only site provided by the stubble left in the Archer field. The corn stubble that was left in the

Figure 5-1. Cross section of corn stalk and leaf sheath showing the protected cavity between them.

Figure 5-2. Cross section of corn cob with enclosing husks showing the protected layers of air.

field at Tall Timbers also included the shelled cobs with up to 20 enclosing husks. This highly protected and insulated site was greatly preferred by the overwintering spiders and insects at Tall Timbers as shown by their virtual absence from the protected leaf base cavities. Figure 5-2 shows in cross section this overwintering site.

In all, 24 species of spiders were found to be using these sites, 10 of which had previously been found to be among the most common and important species in the corn field ecosystem. Besides the spiders, I also collected 25 species of predaceous insects using these same sites to pass the winter. The spiders collected are listed in Table 5-1 and the predaceous insects in Table 5-2.

The variance in the frequency of both spiders and insects wintering in the corn stubble was very high, thus making useful density estimates impossible. Much of the variance, however, was related to the moisture level in the stubble; both insects and spiders were concentrated in the drier stubble.

Discussion

Overwintering spiders have at least three requirements of their quarters. First, the ~~sites~~ must insulate them from the coldest temperatures. Kirchner (1973) studied cold resistance in spiders, finding that many species spending

Table 5-1. Spiders collected during the winter from corn stubble at Archer and Tall Timbers in north Florida, 1982-1984.

FAMILY				
Genus species	Stages ¹	Archer ²	Tall Timbers ³	
DICTYNIDAE				
<u>Dictyna</u> sp.	MJ		X	
THERIDIIDAE				
<u>Achaeranea globosa</u>	EJ,MJ	X	X	
<u>Coleosoma acutiventer</u>	MJ,F		X	
<u>Theridion</u> spp.	LJ,M,F		X	
LINYPHIIDAE				
<u>Eperigone</u> near <u>banksi</u>	EJ		X	
<u>Ceraticellus similis</u>	M		X	
MIMETIDAE				
<u>Mimetus</u> sp.	M		X	
OXYOPIDAE				
<u>Oxyopes salticus</u>	MJ,LJ		X	
<u>Oxyopes scalaris</u>	LJ		X	
AGELENIDAE				
<u>Agelenopsis</u> sp.	M		X	
HAHNIIDAE				
<u>Neoantistea magna</u>	F		X	
LYCOSIDAE				
<u>Pardosa milvina</u>	EJ,MJ,LJ,M,F	X	X	
<u>Pardosa parvula</u>	EJ,MJ,F		X	
<u>Pirata</u> sp.	MJ		X	
ANYPHAENIDAE				
<u>Wulfila saltibunda</u>	MJ,LJ		X	
CLUBIONIDAE				
<u>Castieniara</u> sp.	EJ,MJ		X	
<u>Chiricanthium inclusum</u>	MJ,LJ	X	X	
<u>Clubiona</u> sp.	EG,LJ	X		
<u>Trachelus</u> sp.	MJ,LJ,M,F	X	X	

Table 5-1 -- continued.

FAMILY		Stages ¹	Archer	Tall Timbers
Genus	species			
GNAPHOSIDAE				
<u>Cessonia</u>	<u>bilineata</u>	MJ		X
<u>Poecilochroa</u>	<u>sp.</u>	LJ	X	
<u>Zelotes</u>	<u>rusticus</u>	M		X
THOMISIDAE				
<u>Misumenoides</u>	<u>formosipes</u>	MJ		X
SALTICIDAE				
<u>Metaphidippus</u>	<u>galathea</u>	LJ,M	X	X

1. EJ=Early Juvenile, MJ=Middle Juvenile, LJ=Late Juvenile, M=Male, F=Female.

2. All specimens from Archer were collected from under the leaf sheath.

3. All specimens from Tall Timbers were collected from between the layered husks around the cobs.

Table 5-2. Predaceous insects collected during the winter from corn stubble at Archer and Tall Timbers in northern Florida.

FAMILY Genus species	Stages ¹	Archer ²	Tall Timbers ³
FORFICULIDAE			
<u>Doru aculeatum</u>	M,F	X	X
LABIDURIDAE			
<u>Labidura</u>	M,F	X	X
ANTHOCORIDAE			
<u>Cardiastethus assimilis</u>	ADULTS	X	
<u>Lasiochilus</u> sp?	LI	X	X
LYGAEIDAE			
<u>Geocoris uliginosus</u>	ADULTS		X
<u>Geocoris punctipes</u>	ADULTS		X
MIRIDAE			
<u>Spanogonicus</u> sp.	LI		X
NABIDAE			
<u>Hoplistoscelis</u> <u>deceptivus</u>	ADULTS	X	X
REDUVIIDAE			
<u>Zelus cervicalis</u>	ADULTS		X
CARABIDAE			
<u>Calida decora</u>	ADULTS	X	
COCCINELIDAE			
<u>Scimnus</u> sp.	ADULTS	X	X
STAPHYLINIDAE			
Genus spp. (11 species)	ADULTS		X

1. LI=Late Instar, M=Males, F=Females

2. All specimens from Archer were collected from under the leaf sheath.

3. All specimens from Tall Timbers were collected from between the layered husks around the cobs.

the winter in the open or in hollow plant stems can survive temperatures as low as -16 to -30 C. Air temperatures this low are rarely reached in Florida, but exposed surfaces may be considerably colder than the air due to radiative cooling. Kirchner's study involved species inhabiting central Europe; just how cold tolerant Florida species are has not been investigated.

Second, the spider must avoid desiccation (Edgar and Loenen 1974). Proximity to the soil and protection from the wind should be sufficient in this regard. A third requirement, which has in the past been largely ignored, is the need to avoid predation (Danks 1978). Poikilotherms are particularly vulnerable to birds and mammals due to their decreased metabolic activity at low temperatures. Gunnarsson (1983) found that overwintering spiders on spruce branches had much greater survival when foraging birds were excluded. The preference by over wintering spiders for geometrically complex situations such as birds' nests (Otzen and Schaefer 1980), Spanish moss (Rosenfeld 1911), and in this case, the numerous enclosing bracts around the corn cob, should be important in providing safety from homeothermic predators.

The condition of the stubble left in a corn field is determined by the method used to harvest and by the post-harvest treatment of the field. If the corn is chopped for silage, or if the field is disced and planted to a second crop, virtually no stubble is left. The combine with a

picker-head, which was used at the Archer field, leaves just the corn stalks. On the other hand, the picker-sheller, which was used at Tall Timbers, leaves both the stalks and cobs in the field.

The importance of overwintering sites for predaceous arthropods in agroecosystems is undeniable. However, the corn stubble also provides overwintering sites for herbivorous species as well. Among the species I found wintering in the stubble were Chinch Bugs (Blissus insularis), False Chinch Bugs (Pachybrachius vinctus), Saw Tooth Grain Beetles (Oxyzaephilus surinamensis) and Rice Weevils (Sitophilus oryzae). In addition, Wright et al. (1983) recorded the Southern Corn Billbug (Sphenophorus callosus) overwintering in the crowns of corn plants while in more northern latitudes stubble helps to retain a layer of insulating snow that increases the survival of lepidoptera pupae (Turnock 1984).

Two major pests of corn also make use of post harvest corn trash and the remaining crowns as overwintering sites, namely the European Corn Borer (Ostrinia nubilalis) (Brindley and Dicke 1963) and the Southwestern Cornstalk Borer (Diatraea crambidoides) (Metcalf et al. 1962). Burkhardt (1952) also reported Spodoptera frugiperda larvae pupating in parts of the corn plant. Thus, the use of corn stubble in management of predator populations in areas where these insects are important pests would be unwise, but does point out the need for providing alternative sites. How

these sites might be provided while not benefiting the pest species will require intimate knowledge of the overwintering biology of both pests and beneficials.

CHAPTER VI

CONCLUSION

The determinates of the spider community that develops in a corn field, as for any crop field, can be divided into four groups. First are those associated with the biology and ecology of each individual spider species: life cycle, fecundity, mating and foraging behavior, range of acceptable prey, microclimate requirements, structural requirements for webs and/or retreats, overwintering biology and requirements, and dispersal characteristics. A second group of determinates are those associated with the crop: growth rate, structure, ability to modify the microclimate, phenology (especially as it relates to the production of primary consumers), and the associated herbivore complex.

The third group of determinates are associated with the geographic location of the corn field, the soil, and the vegetation types from which the field was derived. Remnants of the original vegetation may still be important in determining the pool of potential colonists as well as the pool of potential predators, parasites, and competitors of the spiders. Also in this group are the climatic and weather factors which can change so abruptly from area to area, and seasonally.

The final group of community determinates are associated with the management practices applied to the field and surrounding areas: planting date; weed management in the field; cultivation technique, timing, and frequency; technique and timing of irrigation; type, formulation, and timing of insecticide application; fertilization; the previous cropping history; mowing of fence rows (timing and frequency); movement of grazing stock in and out of adjacent areas; weed complexes that result from mowing, grazing, cropping, irrigation, and herbicide use; the number and species of trees left in fence rows and adjacent areas; and the size of the field relative to the area left in more stable habitat that can accommodate the extended life cycles of most spiders. These last two groups of crop spider community determinates are responsible for most of the variability observed in the same crop over time and space.

Another way to view these many factors governing crop spider community development is to instead divide them into those that effect the diversity and magnitude of species in the pool of spiders coming from the surrounding habitat, and into those factors which exclude or restrain the various species in this pool from becoming major components of the community.

Spiders as a group define a loosely linked community. That is, the flow of nutrients and energy within the group is limited, and at least in the field crop situation, compe-

tition at the interspecies level is also limited to infrequent periods of concomitant high density and scarce resources (prey). Then, given the fact that many of the factors structuring the community are constantly changing in time, are far from independent, and that each condition affects each of the different spider species differently, it is clear that predictors of community composition must rely heavily on knowledge of the biology and ecology of each species.

The above discussion leads to several lines of further research that are necessary to better understand the development of spider communities in crop fields and thus potential ways of managing the community to the benefit of better pest control.

First of these is rather straight forward descriptions of the biology and ecology of the spiders. Fewer than a dozen spiders of the eastern United States have had the details of their life cycles recorded. Such studies of spider's natural history must include both carefully controlled laboratory rearing and intense field observations of behavior, habitat, prey selection, overwintering biology, dispersal behavior and population dynamics. This information will give us valuable clues as to how to make the agroecosystem more or less favorable for a given species (or a set of species if it is found that important aspects of their life histories and habitats are similar).

Another area where information is needed pertains to the influence of crop species, physiognomy, spacing, weed management, prey abundance/diversity and agronomic techniques on the resulting spider community. Carefully controlled field plot experiments similar to those conducted by Altieri (1979) on the influence of crop field diversity on predator diversity, would help further answer this basic question as to whether or not a particular crop produces a characteristic community of spiders.

More information on dispersal behavior is necessary and should be directed at producing an accurate, time dependent list of spiders in a given area that are potential colonists of crop fields. Experiments designed to determine the significance of this list, can take advantage of the fact that much of the variation in the pool of dispersing spiders is due to the nature and management of the surrounding habitat, the time of year and previous and current weather conditions.

Spiders which balloon and occur in crop fields must have mechanisms for continuing from season to season. The sites and stages of the overwintering populations of all the important species must be determined. Multiple regression analysis might be useful in isolating the weather phenomena responsible for seasonal mortality and population perturbations as well as dispersal behavior.

the following events are likely have taken place: A population of the spider must been present in the surrounding habitat having found suitable overwinter sites, a portion of that population must have been induced to disperse in the direction of the crop field, there must not have been an abundance of intervening favorable habitat, and finally the spider must have been induced to suspend dispersing (at least momentarily) once within the bounds of the field. The density of the population in the plot is a function of many factors, which could be deciphered through a combination of careful field plot design and ecological observation inspired by the field plot results.

But what changes in the crop field spider community are in fact desirable or even possible? The prey selection of web building spiders is easier to assess than that of the vagrant hunters. From the present data, it appears that a large portion of the diet of the small orb weavers (Araneidae) consists of small flying insects, of which parasitic hymenoptera form a major part. The vagrant hunting Clubionidae, Oxyopidae, and Salticidae on the other hand appear to be heavy predators of lepidoptera eggs and larvae, but determining the level of this predation may require more technical methods such as labeling or immunoassay analysis of field collected spiders. Inductive means of assessing this predation might be possible through manipulation of the levels of prey or spider.

Given a deduced level of potential predation by a spider and a level of predation that is desired at the field level, can the population be elevated to the necessary level without inducing intraspecific, self limiting behavior such as territoriality? Are the stage or stages of the arriving spiders (balloonists) those which could provide significant control and/or is there sufficient alternate prey prior to the period when the pest species arrives? Further, it would generally be impractical to release spiders as in an augmentation program; the number of spiders available per unit area of crop field being dependent on the area and density of source habitat(s) and the size of the field. The economics of modern agriculture tend to favor a minimum of source habitat versus large contiguous fields.

It is generally agreed that spiders, unlike the specific predators and parasitoids, are best at controlling populations during the lag phase of establishment and should not be expected to track exponentially expanding populations. Thus the most practical route might be to manage the agroecosystem so as to favor an assemblage of spider species of various ages that use several stages of the pest species as prey, and to limit those species groups of spiders which interfere with the activities of the specific predators and parasitoids.

Due to the high productivity of corn and the relatively low use of insecticides in it, corn is a potential source

of serious pests such as Spodoptera spp., Heliothis spp., Diatraea spp., pentatomids, grasshoppers and spider mites that can move into other valuable crops. Moreover, because corn is grown on so many hectares and is part of nearly every agroecosystem in Florida, the United States, and virtually throughout the world, management of the pests, predators and parasites in this crop takes on considerable significance. Finally, legumes frequently dominate the complex of weeds which emerges as the corn field matures; since a large percentage of the corn field spiders move to these weeds, they enter the population dynamics picture of numerous other serious pests (and their parasitoids) of agricultural systems.

Corn is also one of the most important sources of starch in small, diversified cropping systems of the subsistence farmers in developing countries. Due to their economic situation, naturally occurring biological control is frequently the only control; the role of spiders on these farms might be particularly important; and achievable because of the added benefit of habitat diversity (Riechert and Lockley 1984).

Because spiders, like the pests we wish them to help regulate, are mobile, we must consider ecosystem wide dynamics and management strategies. Each crop field, weed patch, pasture, or area of natural vegetation in the system

can act as either a source or a sink (trap crop) for pest species, predators, and parasitoids as well as spiders. The interaction of the biological characteristics of the component species, their inter- and intraspecific dynamics, and the parameters set forth by management of the ecosystem and the prevailing climatic and weather patterns will ultimately control the degree of pest control that is achieved.

REFERENCES CITED

- Aguilar-F., P. G. 1965. Notas sobre las arañas en el campo cultivado. Revista Peruana de Entomol. 8:80-83.
- Aguilar-F., P. G. 1968 Araneida frecuentes en el algodónero. Revista Peruana de Entomol. 11:92-95.
- Altieri, M. A. 1979 The design of pest stable corn agroecosystems based on the manipulation of insect populations through weed management. Ph.D. Dissertation, Univ. Fla.
- Altieri, M. A., and J. W. Todd 1981. Some influences of vegetation diversity on insect communities of Georgia soybean fields. Protection Ecol. 3:331-338.
- Altieri, M. A., and W. H. Whitcomb 1979. Predaceous arthropods associated with Mexican tea (Chenopodium ambrosioides) in North Florida. Fla. Entomol. 62:175-182.
- Altieri, M. A., and W. H. Whitcomb 1980. Predaceous arthropods associated with Camphorweed (Heterotheca subaxilaris (Lamb.)) in North Florida. J. Georgia Entomol. Soc. 15:290-299.
- Archer, A. F. 1942. Alabama spiders of the family Mimetidae. Pap. Michigan Acad. Sci. 27:183-193.
- Archer, T. L., E. D. Bynum, Jr., and A. Knutson 1983. Winter management of the southwestern cornborer (Lepidoptera: Pyralidae), using several cultural practices on different dates. J. Econ. Entomol. 76:872-876.
- Baily, C. L., and H. L. Chada 1968. Spider populations in grain sorghum. An. Entomol. Soc. Amer. 61:567-571.
- Berman, J. D., and H. W. Levi 1971. The orb weaver genus Neoscona in North America (Araneae: Araneidae). Bull. Mus. Comp. Zool. 141:465-500.
- Bigger, M. 1981. Observations on the insect fauna of shaded and unshaded Amelondo cocoa. Bull. Entomol. Res. 71:107-119.

- Bishop, A. L. 1981. The spatial dispersion of spiders in a cotton ecosystem. *Australian J. Zool.* 29:15-24.
- Bishop, S. C., and C. R. Crosby 1932. Studies in American spiders: The genus Grammonota. *J. New York Entomol. Soc.* 40:393-421.
- Blackwall J. 1827. Observations and experiments, made with a view to ascertain the means by which the spiders that produce gossamer effect their aerial excursions. *Trans. Linn. Soc. London* 15:449-459.
- Boiteau, G. 1984. Effect of planting date, plant spacing, and weed cover on populations of insects, arachnids and entomophthoran fungi in potato fields. *Environ. Entomol.* 13:751-756.
- Bowers, M. A., and J. H. Brown 1982. Body size and coexistence in desert rodents: Chance or community structure. *Ecology* 63:391-400.
- Brady, A. R. 1964. The lynx spiders of North America, north of Mexico (Araneae:Oxyopidae). *Bull. Mus. Comp. Zool.* 131:429-518.
- Brindley, T. A., and F. F. Dicke 1963. Significant developments in European corn borer research. *Ann. Rev. Entomol.* 8:155-176.
- Bristowe, W. S. 1929. The distribution and dispersal of spiders. *Proc. Zool. Soc., London* 43:633-657.
- Bristowe, W. S. 1939-1941. The comity of spiders. *Ray Society, London*. Vol. I:1-228 (1939), Vol. II:229-560 (1941).
- Burkhardt, C. C. 1952. Feeding and pupating habits of the fall armyworm in corn. *J. Econ. Entomol.* 45:1035-1037.
- Burleigh, J. G., J. H. Young, and R. D. Morrison 1973. Strip cropping's effect on beneficial insects and spiders associated with cotton in Oklahoma. *Environ. Entomol.* 2:281-285.
- Buschman, L. L., H. N. Pitre, and H. F. Hodges 1984. Soybean cultural practices: effect on populations of Geocoris, nabids, and other soybean arthropods. *Environ. Entomol.* 13:305-317.
- Carrico, J. E. 1972. The Nearctic spider genus Pisaurina (Pisauridae). *Psyche* 79:295-310.

- Carroll, D. 1978. Nocturnal behavior of some day-wandering arboreal spiders. *Peckhamia* 1:30-31.
- Carroll, C. R., and D. H. Janzen 1973. Ecology of foraging by ants. *Ann. Rev. Ecol. Syst.* 4:231-258.
- Chamberlin, R. V., and W. J. Gertsch 1958. The spider family Dictynidae in America north of Mexico. *Bull. Am. Mus. Nat. Hist.* 116:1-152.
- Cherrett, J. M. 1964. The distribution of spiders on the Moor House National Nature Reserve, Westmorland. *J. Anim. Ecol.* 33:27-48.
- Chew, R. M. 1961. Ecology of the spiders of a desert community. *J. New York Entomol. Soc.* 69:5-41.
- Chiverton, P. 1982. Effect of polyphagous predators on the establishment phase of the bird-cherry oat aphid (*Rhopalosiphum padi*) infesting spring barley. *Vaxtskyddsrapporter* 20:177-181.
- Clarke, R. D., and P. R. Grant 1968. An experimental study of the role of spiders as predators in forest litter community. Part 1. *Ecology* 49:1152-1154.
- Clausen, I. H. S. 1983. Weight-length relations of 8 species of spiders (Araneae) from Denmark. *Entomol. Medd.* 50:139-144.
- Clercq, R. de, and R. Pietraszko 1983. Epigeal arthropods in relation to predation of cereal aphids. IN *Aphid Antagonists*. R. Cavalloro, editor. A. A. Balkema, Merelbeke, Belgium. pp.88-92.
- Cloudsley-Thompson, J. L. 1962. Microclimate and the distribution of terrestrial arthropods. *An. Rev. Entomol.* 7:199-222.
- Colebourn, P. H. 1974. The influence of habitat structure on the distribution of Araneus diadematus Clerck. *J. Anim. Ecol.* 43:401-409.
- Comstock, J. H. 1948. *The spider book*. Comstock Pub., Ithaca, New York. 729pp.
- Corn Refiners Association 1982. *Corn Annual 1982*. Corn Refiners Association, Washington D. C. 28pp.

- Coyle, F. A. 1985. Ballooning behavior of Ummidia spiderlings (Araneae, Ctenizidae). J. Arachnology 13:137-138.
- Craig, C. L., A. Okubo, V. Andreassen (In Press). Effect of spider orb-web and insect oscillations on prey interception. J. Theor. Biol.
- Crosby, C. R., and S. C. Bishop 1928. Revision of the spider genera Erigone, Eperigone and Catabrithorax (Erigoneae). Bull. New York State Mus. 278:3-74.
- Crosby, C. R., and S. C. Bishop 1933. American spiders: Erigoneae, males with cephalic pits. An. Entomol. Soc. Amer. 26:105-182.
- Culin, J. D., and K. V. Yeargan 1982. Feeding behavior and prey of Neoscona arabesca (Araneae: Araneidae) and Tetragnatha laboriosa (Araneae: Tetragnathidae) in soybean fields. Entomophaga 27:417-424.
- Culin, J. D., and K. V. Yeargan 1983a. Comparative study of spider communities in alfalfa and soybean ecosystems: Foliage dwelling spiders. An. Entomol. Soc. Am. 76:825-831.
- Culin, J. D., and K. V. Yeargan 1983b. Comparative study of spider communities in alfalfa and soybean ecosystems: Ground-surface spiders. An. Entomol. Soc. Am. 76:832-838.
- Danks, H. V. 1978. Modes of seasonal adaptation in the insects. I. Winter survival. Can. Entomol. 110:1167-1205.
- Dean, D. A., and W. L. Sterling 1985. Size and phenology of ballooning spiders at two locations in eastern Texas. J. Arachnol. 13:111-120.
- Dean, D. A., W. L. Sterling, and N. V. Horner 1982. Spiders in eastern Texas cotton fields. J. Arachnol. 10:251-260.
- Dennison, D. F., I. D. Hodkinson 1983. Structure of the predatory beetle community in a woodland soil ecosystem I. prey selection. Pedobiologia 25(2):109-115.
- Desender, K. 1982. Ecological and faunal studies on Coleoptera in agricultural land: 2. Hibernation of carabidae in agro-ecosystems. Pedobiologia 23:295-303.

- Dicke, F. F., and J. L. Jarvis 1962. The habits and abundance of Orius insidiosus (Say) (Hemiptera: Anthoridae) on corn. J. Kansas Entomol. Soc. 35:339-344.
- Dippenaar-Schoeman, A. S. 1979. Spider communities in strawberry beds: Seasonal changes in numbers and species composition. Phytophylactica 11:1-4.
- Doane, J. F., and C. D. Dondale 1979. Seasonal captures of spiders (Araneae) in a wheat field and its grassy borders in central Saskatchewan. Can. Entomol. 111:439-445.
- Dondale, C. D. 1956. Annotated list of spiders (Araneae) from apple trees in Nova Scotia. Can. Entomol. 88:697-700.
- Dondale, C. D. 1970. Spiders of Heasman's meadow near Belleville, Ontario. Proc. Entomol. Soc. Ontario 101:62-69.
- Dondale, C. D., and J. H. Redner 1961. Revision of the aureolus group of the genus Philodromus (Araneae: Thomisidae) in North America. Can. Entomol. 93:199-222.
- Dondale, C. D., and J. H. Redner 1968. The imbecillus and rufus groups of the spider genus Philodromus in North America. Entomol. Soc. Can. Mem. 55:1-58.
- Dondale, C. D., and J. H. Redner 1984. Revision of the Milvina group of the wolf spider genus Pardosa (Araneae: Lycosidae). Psyche 91:67-117.
- Dondale, C. D., B. Parent, and D. Pitre 1979. A 6-year study of spiders (Araneae) in a Quebec apple orchard. Can. Entomol. 111:377-380.
- Douglas, W. A., W. H. Whitcomb, L. W. Hepner, V. M. Kirk, and R. Davis 1966. Some cicadellidae (Homoptera) collected from corn in the southeastern United States. An. Entomol. Soc. Am. 59:393-396.
- Dritschilo, W., and T. L. Erwin 1982. Responses in abundance and diversity of cornfield carabid communities to differences in farm practices. Ecology 63:900-904.
- Duffy, E. 1962. A population study of spiders in limestone grassland: The field-layer fauna. Oikos 13:15-33.

- Duffy, E. 1956. Aerial dispersal in a known spider population. *J. Anim. Ecol.* 25:85-111.
- Duffy, E. 1978. Ecological strategies in spiders including some characteristics of spiders in pioneer and mature habitats. *Symp. Zool. Soc. Lond.* 42:109-123.
- Dumas, B. A., W. P. Boyer, and W. H. Whitcomb 1962. Effects of time of day on surveys of predaceous insects in field crops. *Fla. Entomol.* 45:121-128.
- Eason, R. R., W. B. Peck, and W. H. Whitcomb 1967. Notes on spider parasites, including a reference list. *J. Kansas Entomol. Soc.* 40:422-434.
- Eberhard, W. G. 1971. The ecology of the web of Uloborus diversus (Araneae: Uloboridae). *Oecologia.* 6:328-342.
- Eberhard, W. G. 1977. Aggressive chemical mimicry by a bolas spider. *Science* 198:1173-1174.
- Edgar, W. E., and M. Loenen 1974. Aspects of the overwintering habitat of the wolf spider Pardosa lugubris. *J. Zool.* 172:383-387.
- Edwards, G. B. 1980. Taxonomy, ethology, and ecology of Phidippus (Araneae: Salticidae) in eastern North America. Ph.D. Dissertation. Univ. Fla. 354pp.
- Edwards, G. B., J. F. Carroll, and W. H. Whitcomb 1974. Stoidis aurata (Araneae: Salticidae) a spider predator of ants. *Fla. Entomol.* 57:337-346.
- Edwards, R. J. 1958. The spider subfamily Clubioninae of the United States, Canada and Alaska (Araneae: Clubionidae). *Bull. Mus. Comp. Zool.* 118-365-436.
- Enders, F. 1975. Change of web site in Argiope spiders (Araneidae). *Amer. Mid. Nat.* 94:484-490.
- Everly, R. T. 1938a. Spiders and insects found associated with sweet corn with notes on the food and habits of some species. I. Arachnida and Coleoptera. *Ohio J. of Science* 38(3):136-148.
- Everly, R. T. 1938b. Spiders and insects found associated with sweet corn with notes on the food and habits of some species. II. Ephemeroptera, Lepidoptera, Neuroptera, Odonata, Orthoptera, Thysanoptera and Trichoptera. *Ohio J. of Science* 38(6):311-315

- Everly, R. T. 1939a. Spiders and insects found associated with sweet corn with notes on the food and habits of some species. III. Hymenoptera. Ohio J. of Science 39(1):48-51.
- Everly, R. T. 1939b. Spiders and insects found associated with sweet corn with notes on the food and habits of some species. IV. Diptera and Hemiptera. Ohio J. of Science 39(1):52-56.
- Everly, R. T. 1940. Spiders and insects found associated with sweet corn with notes on the food and habits of some species. V. Homoptera and summary. Ohio J. of Science 40(3):143-146.
- Exline, H., and H. W. Levi 1962. American spiders of the genus Argyrodes (Araneae:Theridiidae). Bull. Mus. Comp. Zool. 127:75-204.
- Foelix, R. F. 1982. Biology of spiders. Harvard Univ. Press, Cambridge, Mass. 306pp.
- Fox, C. J. S., and C. D. Dondale 1972. Annotated list of spiders (Araneae) from hayfields and their margins in Nova Scotia. Can. Entomol. 104:1911-1915.
- French, T. W. 1984. Dietary overlap of Sorex longirostris and S. cinereus in hardwood floodplain habitats in Vigo County, Indiana. Amer. Midl. Nat. 111:41-46.
- Futuyma, D. J., and F. Gould 1979. Associations of plants and insects in a deciduous forest. Ecol. Monogr. 49:33-50.
- Fye, R. E. 1972. The interchange of insect parasites and predators between crops. PANS 18:143-146.
- Gadgil, M. 1971. Dispersal: Population consequences and evolution. Ecology. 52:253-261.
- Gertsch, W. J. 1939. A revision of the typical crab spiders (Misumeninae) of America north of Mexico. Bull. Am. Mus. Nat. Hist. 76:277-442.
- Gertsch, W. J. 1979. American spiders. Van Nostrand. Reinhold, New York. 274pp.
- Glick, P. A. 1939. The distribution of insects, spiders, and mites in the air. USDA Tech. Bull. No. 673, 105pp.

- Gonzalez, D., and L. T. Wilson 1982. A food web approach to economic thresholds: a sequence of pests/predaceous arthropods on California cotton. *Entomophaga* 27:31-43.
- Gowan, T. D. 1985. The life history and reproduction of the wolf spider Lycosa lenta Hentz. Ph.D. Dissertation, Univ.Fla.
- Greenstone, M. H. 1978. The numerical response to prey availability of Pardosa ramulosa (McCook) (Araneae: Lycosidae) and its relationship to the role of spiders in the balance of nature. *Symp. Zool. Soc. Lond.* 42:183-193.
- Greenstone, M. H. 1985. Spider ballooning: development and evaluation of trapping protocols. (In preparation).
- Greenstone, M. H. 1981. Ballooning frequency and habitat predictability in two wolf spider species (Lycosidae: Pardosa). *Fla.Entomol.* 65(1):83-89.
- Gunnarsson, B. 1983. Winter mortality of spruce-living spiders: effect of spider interactions and bird predation. *Oikos* 40:226-233.
- Hallander, H. 1970. Range and movement of the wolf spiders Pardosa chelata (O.F.Muller) and P. pullata (Clerck). *Oikos* 18:360-364.
- Holling, C. S. 1965. The functional response of predators to prey density and its role in mimicry and population regulation. *Can. Entomol.* 45:1-60.
- Homann, H. 1971. Die Augen der Araneae. *Zeitschr. Morph. Tiere* 69:201-272.
- Homann, H. 1975. Die Stellung der Thomisidae und der Philodromidae in System der Araneae. *Zeitschr. Morph. Tiere* 80:181-202.
- Horner, N. V. 1972. Metaphidippus galathea as a possible biological control agent. *J. Kansas Entomol. Soc.* 45:324-327.
- Horner, N. V. 1975. Annual dispersal of jumping spiders in Oklahoma. *J. Arachnology* 2:101-105.
- Horner, N. V., and K. J. Starks 1972. Bionomics of the jumping spider Metaphidippus galathea. *An. Entomol. Soc. Am.* 65:602-607.

- House, G. J., and J. N. All 1981. Carabid beetles in soybean agroecosystems. *Envir. Entomol.* 10:194-196.
- Howell, J. O., and R. C. Pienkowski 1971. Spider populations in alfalfa, with notes on spider prey and effect of harvest. *J. Econ. Entomol.* 64:163-168.
- Isenhour, D. J., and K. V. Yeargan 1981. Effect of crop phenology on Orius insidiosus populations on strip-cropped soybeans and corn. *J. Georgia Entomol. Soc.* 16:310-322.
- Jeffords, M. R., G. C. Helm, and M. Kogan 1983. Overwintering behavior and spring colonization of soybean by the bean leaf beetle (Coleoptera:Chrysomelidae) in Illinois. *Environ. Entomol.* 12:1459-1463.
- Jennings, D. T. 1971. Plant associations of Misumenops coloradensis Gertsch in central New Mexico. *Southwest Naturalist* 16:201-207.
- Jugenheimer, R. W. 1976. Corn: Improvement, seed production, and uses. John Wiley, New York 670pp.
- Kaczmarek, W., K. Sierakowski, and A. Wasilewski 1981. Food preference of insectivorous birds in the forest ecosystems of the Kampinos National Park. *Ekologia Polska* 29:499-518.
- Kagan, M. 1943. The araneida found on cotton in central Texas. *Am. Entomol. Soc. Am.* 36:257-258.
- Kartohardjono, A., and E. A. Heinrichs 1984. Populations of the brown planthopper, Nilaparvata lugens (Stal) (Homoptera:Delphacidae), and its predators on rice varieties with different levels of resistance. *Environ. Entomol.* 13:359-365.
- Kaston, B. J. 1965. Some little known aspects of spider behavior. *Am. Midl. Natur.* 73:336-356.
- Kaston, B. J. 1970. Comparative biology of American black widow spiders. *San Diego Soc. Nat. Hist. Trans.* 16:33-82.
- Kaston, B. J. 1978. How to know the spiders, 3rd edit. Wm. C. Brown, Dubuque, Iowa 272pp.
- Kaston, B. J. 1981. Spiders of Connecticut. *State Geolog. and Natur. Hist. Survey of Conn. Bull.* 70, revised edit. 1020pp.

- Kieffer, J. N., C. H. Shanks, Jr., and W. J. Turner 1983. Populations and control of insects and spiders contaminating mechanically harvested red raspberries in Washington and Oregon. *J. Econ. Entomol.* 76:649-653.
- Kirchner, W. 1973. Ecological aspects of cold resistance in spiders IN *Effects of temperature on ectothermic organisms.* edit. W. Weiser. New York 298pp.
- Komarek, E. V. 1951. Florida corn. State of Florida, Dept. Agric. 596pp.
- Krombein, V. V. 1967. Trap-nesting wasps and bees: life histories, nests and associates. Smithsonian Press, Washington D. C. 570pp.
- Lamb, W. O. 1980. Predispersal seed predation of the Platte thistle and its effect on seed production. Ph.D. Thesis, Univ. of Nebra. 137pp.
- Landers, P. B., and J. A. MacMahon 1980. Guilds and community organization: analysis of an oak woodland avifauna in Sonora, Mexico. *The Auk* 97:351-367.
- Laster, M. L., and J. R. Brazzel 1968. A comparison of predator population in cotton under different control programs in Mississippi. *J. Econ. Entomol.* 61:714-718.
- Lauda, S. 1982. Inflorescence spiders: a cost benefit analysis for the host plant, Haplopappus venetus Blake (Asteraceae). *Oecologia* 55:185-191.
- Leigh, T. F., and R. E. Hunter 1969. Predacious spiders in California cotton. *California Agric.* 23(1):4-5.
- LeSar, C. D., and J. D. Unzicker 1978. Soybean spiders: Species composition, population densities, and vertical distribution. *Illinois Nat. Hist. Surv. Notes.* No. 107.
- Levi, H. W. 1955. The spider genera Coressa and Achaeranea in America north of Mexico. *Amer. Mus. Novit.* 1718:1-33.
- Levi, H. W. 1957. The spider genera Enoplognatha, Theridion, and Paidisca in America North of Mexico. *Bull. Amer. Mus. Nat. Hist.* 112:1-124.
- Levi, H. W. 1963. American spiders of the genus Theridion (Araneae, Theridiidae). *Bull. Mus. Comp. Zool.* 129:481-589.

- Levi, H. W. 1968. The spider genera Gea and Argiope in America. Bull. Mus. Comp. Zool. 136:319-352.
- Levi, H. W. 1971. The orb weaver genera Singa and Hyposinga in America (Araneae:Araneidae). Psyche 78:229-256.
- Levi, H. W. 1975. The American orb weaver genera Larina, Cercidia and Mangora north of Mexico (Araneae:Araneidae). Bull. Mus. Comp. Zool. 147:101-135.
- Levi, H. W. 1976. The orb weaver genera Verrucosa, Acanthepeira, Wagneriana, Acacesia, Wixia, Scoloderus and Alpaída north of Mexico (Araneae:Araneidae). Bull. Mus. Comp. Zool. 147:351-391.
- Levi, H. W. 1977. The American orb weaver genera Cyclosa, Metazygia and Eustala north of Mexico (Araneae,Araneida). Bull. Mus. Comp. Zool. 148:61-127.
- Levi, H. W. 1980. The orb weaver genus Mecynogea, the subfamily Metinae, and the genera Pachygnatha, Glenognatha, and Azilia of the subfamily Tetragnathinae north of Mexico. Bull. Mus. Comp. Zool. 149:1-74
- Levi, H. W., and L. R. Levi 1962. The genera of the spider family Theridiidae. Bull. Mus. Comp. Zool. 127:1-71
- Lewin, R. 1983a. Santa Rosalia was a goat. Science. 221:636-639.
- Lewin, R. 1983b. Predators and hurricanes change ecology. Science. 221:737-740.
- Lockley, T. C., J. W. Smith, and C. R. Parencia 1979. Population fluctuations of two groups of spiders from selected cotton fields in Panola and Pontotoc Counties, Mississippi, 1977. Southwest Entomol. 4:20-24.
- Loke, W. H., T. R. Ashley, and R. I. Sailer 1983. Influence of fall armyworm, Spodoptera frugiperda, (Lepidoptera: Noctuidae) larvae and corn plant damage on host finding in Apanteles marginiventris (Hymenoptera: Braconidae). Envir. Entomol. 12:911-915.
- Luczac, J. 1975. Spider communities of the crop fields. Polish Ekol. Stud. 1:93-110.
- Luczac, J. 1979. Spiders in agrocoenoses. Polish Ekol. Stud. 5:151-200.

- Mansour, F. , D. B. Richmond, and W. H. Whitcomb 1983. Spider management in agroecosystems: habitat manipulation. *Environ. Management* 7:43-49.
- Mansour, F., J. W. Ross, G. B. Edwards, W. H. Whitcomb, D. Richman. 1982. Spiders of Florida citrus groves. *Fla. Entomol.* 65(4):514-522.
- McDaniel, S. G., and D. A. Dean 1981. Predators of tobacco budworm larvae in Texas cotton. *Southwest Entomol.* 6:102-108.
- McDaniel, S. G., and W. L. Sterling 1979. Predator determination and efficiency on Heliothis virescens eggs in cotton using ³²P. *Envir. Entomol.* 8:1083-1087.
- McDaniel, S. G., and W. L. Sterling 1982. Predation of Heliothis virescens (F.) eggs on cotton in east Texas. *Envir. Entomol.* 11:60-66.
- Metcalf, C. L., W. P. Flint, and R. L. Metcalf 1962. Destructive and useful insects, their habits and control. McGraw-Hill, New York. 1087pp.
- Monk, C. D. 1965. Southern mixed hardwood forests of north-central Florida. *Ecol. Monogr.* 55:335-354.
- Morse D. H., and R. S. Fritz 1982. Experimental and observational studies of patch choice at different scales by the crab spider Misumena vatia. *Ecology* 63(1):172-182.
- Muma, M. H., and W. J. Gertsch 1964. The spider family Uloboridae in North America north of Mexico. *Amer. Mus. Novitates* 2196:1-43.
- Muniappan, R., and H. L. Chada 1970. Biological control of the greenbug by the spider Phidippus audax. *J. Econ. Entomol.* 63:1712.
- Neal, T. M. 1974. Predaceous arthropods in the Florida soybean agroecosystem. M.S. Thesis, Univ. of Florida, 196pp.
- Nyffeler, M. 1982. Field studies on the ecological role of the spiders as insect predators in agroecosystems (abandoned grassland, meadows, and cereal fields). Ph.D. Thesis. Swiss. Fed. Inst. Tech. Zurich, Switzerland.
- Okuma, C. 1981. Air borne spiders collected over the East China Sea. *Jap. J. Appl. Entomol. Zool.* 25:296-8.

- Otzen, W., and M. Schaefer 1980. Hibernation of arthropods in bird nests: contribution to winter ecology. Zool. Jahrb. Abt. Syst. Oekol. Geogr. Tiere. 107:435-448.
- Peck, W. B., and W. H. Whitcomb 1970. Studies on the biology of a spider, Chiricanthium inclusum (Hentz). Arkans. Agric. Exper. Sta. Bull. 753:1-7.
- Pieters, E. P., and W. L. Sterling 1974. Aggregation indices of cotton arthropods in Texas. Environ. Entomol. 3(4):598-600.
- Pietraszko, R., and R. de Clercq 1982. Influence of organic matter on epigeic arthropods. Mededelingen van dem Faculteit Landbouwweten schappen Rijksuniversiteit Gent. 47:721-728.
- Plagens, M. J. 1981. Bionomics of the crab spider genus Misumenops in two Arizona cotton fields. M.S. Thesis, Univ. Ariz., 61pp.
- Plagens, M. J. 1983. Populations of Misumenops (Araneida:Thomisidae) in two Arizona cotton fields. Envir. Entomol. 12:572-575.
- Platnick, N. I. 1974. The spider family Anyphaenidae in America north of Mexico. Bull.Mus. Comp.Zool. 146:205-266.
- Platnick, N. I., and M. U. Shadab 1974a. A revision of the tranquillus and speciosus groups of the spider genus Trachelus (Araneae:Clubionidae) in North and Central America. Amer. Mus. Novit. 2553:1-34.
- Platnick, N. I., and M. U. Shadab 1974b. A revision of the bispinosus and bicolor groups of the spider genus Trachelus (Araneae:Clubionidae) in North and Central America and the West Indies. Amer. Mus. Novit. 2560:1-34.
- Platnick, N. I., and M. U. Shadab 1975. A revision of the spider genus Gnaphosa (Araneae:Gnaphosidae) in America. Bull. Am. Mus. Nat. Hist. 155:1-66.
- Price, P. W. 1975. Insect ecology. John Wiley, New York, N.Y. 514pp.
- Price, P. W. 1976. Colonization of crops by arthropods: non-equilibrium communities in soybean fields. Envir. Entomol. 5:605-611.

- Ragsdale, D. W., A. D. Larson, and L. D. Newsom 1981. Quantitative assessment of the predators of Nezara viridula eggs and nymphs within a soybean agroecosystem using an ELISA. *Envir. Entomol.* 10:402-405.
- Rau, P. 1935. The spider prey of the mud wasp, Sceliphron caementarium. *Entomol. News* 46:267-270.
- Reiskind, J. 1969. The spider subfamily Castianeirinae of North and Central America (Araneae, Clubionidae). *Bull. Mus. Comp. Zool.* 138:163-325.
- Richter, C. J. J. 1970. Aerial dispersal in relation to habitat in eight wolf spider species (Pardosa, Araneae, Lycosidae). *Oecologia* 5:200-214.
- Riechert, S. E. 1973. The effects of thermal balance and prey availability on distribution patterns of the desert spider Agelenopsis aperta (Gertsch). Ph.D. Thesis, Univ. Wisconsin.
- Riechert, S. E. 1974. Thoughts on the ecological significance of spiders. *BioScience* 24(6):352-356.
- Riechert, S. E. 1981. The consequences of being territorial: Spiders, a case study. *Amer. Natural.* 117:871-892.
- Riechert, S. E., and A. B. Cady 1983. Patterns of resource use and tests for competitive release in a spider community. *Ecology* 64:899-913.
- Riechert, S. E., and T. Lockley 1984. Spiders as biological control agents. *Ann. Rev. Entomol.* 29:299-320.
- Robinson, J. V. 1981. The effect of architectural variation in habitat on a spider community: an experimental field study. *Ecology*. 62(1):73-80.
- Rogers, C. E., and N. V. Horner 1977. Spiders of guar in Texas and Oklahoma. *Environ. Entomol.* 6:523-524.
- Root, R. B. 1973. Organization of a plant arthropod association in simple and diverse habitats: The fauna of collards (Brassica oleraceae). *Ecol. Monogr.* 43:95-124.
- Rosenfeld, A. H. 1911. Insects and spiders in Spanish moss. *J. Econ. Entomol.* 4:398-409.

- Roth, V. D. 1964. The taxonomic significance of the spider trochanter. *An. Entomol. Soc. Am.* 57:759-766.
- Salmon, J. T., and N. V. Horner 1977. Aerial dispersion of spiders in north central Texas. *J. Arachnol.* 5:153-157.
- Slosser, J. E., R. J. Fewin, J. R. Price, L. J. Meinke, and J. R. Bryson 1984. Potential of shelter belt management for boll weevil (Coleoptera:Cucurliionidae) control in Texas Rolling Plains. *J. Econ. Entomol.* 77:377-385
- Sousa, W. P. 1984. The role of disturbance in natural communities. *Ann. Rev. Ecol. Syst.*
- Southwood, T. R. E. 1978. Ecological methods with particular reference to the study of insect populations. Chapman and Hall, London. 524pp.
- Spect, H. B., and C. D. Dondale 1960. Spider populations in New Jersey apple orchards. *J. Econ. Entomol.* 53:810-814.
- Stadelbacher, E. A., and T. C. Lockley 1983. The spiders of Geranium dissectum Linneaus in Washington County, Mississippi. *J. Georgia Entomol. Soc.* 18:398-402.
- Strong, D. R., Jr. 1982. Harmonious coexistence of hispine beetles on Heliconia in experimental and natural communities. *Ecology* 63:1039-1049.
- Taylor, L. R. 1984. Assessing and interpreting the spatial distributions of insect populations. *Ann. Rev. Entomol.* 29:321-357.
- Thornhill, W. A. 1983. The distribution and probable importance of linyphiid spiders living on the soil surface of sugar-beet fields. *Bull. Br. Arachnol. Soc.* 6:127-136.
- Trail, D. S. 1980. Predation by Argyrodes (Theridiidae) on solitary and communal spiders. *Psyche.* 87:349-355.
- Turnbull, A. L. 1964. The search for prey by a web building spider Achaeranea tepidariorum (C.L.Kock)(Araneae, Theridiidae). *Can. Entomol.* 96:568-579.
- Turner, B. J. 1984. Predator pressure on the arboreal epiphytic herbivores of larch trees in southern England. *Ecological Entomol.* 9:91-100.
- Turnock, W. J., and R. J. Bilodeau 1984. Survival of pupae of Mamestra configurata (Lepidoptera:Noctuidae) and 2

- of its parasites in untilled and tilled soil. Can. Entomol. 116:257-268.
- USDA-Soil Conservation Service 1980. Special soil survey report maps and interpretations, Alachua County, Florida. USDA-Soil Conservation Service.
- Wallace, H. K. 1937. The use of the headlight in collecting nocturnal spiders. Entomol. News 48:107-111.
- Wallace, H. K., and H. Exline 1978. Spiders of the genus Pirata in North America, Central America and the West Indies (Araneae:Lycosidae). J. Arachnol. 5:1-112.
- Wheeler, A. G., Jr. 1973. Studies on the arthropod fauna of alfalfa V. Spiders (Araneida). Can. Entomol. 105:425-432.
- Whitcomb, W. H. 1967. Field studies on predation of the second-instar bollworm, Heliothis zea (Boddie) (Lepidoptera:Noctuidae). J. Georgia Entomol. Soc. 2:113-118.
- Whitcomb, W. H. 1973. Natural populations of entomophagous arthropods and their effect on the agroecosystem. IN Proceedings of the Summer Institute on Biological Control of plants, insects and diseases. Univ. Press of Mississippi. pp.150-169.
- Whitcomb, W. H. 1980. Sampling spiders in soybean fields. IN Sampling methods in Soybean Entomology. M. Kogan and D. C. Herzog, editors. Springer-Verlag, New York, pp.544-558.
- Whitcomb, W. H. 1984. Personal communication.
- Whitcomb, W. H., and R. Eason 1967. Life history and predatory importance of the striped lynx spider (Araneida: Oxyopidae). Ark. Acad. Sci. Proc. 21:54-58.
- Whitcomb, W. H., H. Exline, and R. C. Hunter 1963. Spiders of the Arkansas cotton field. An. Entomol. Soc. Am. 56:653-660.
- Whitcomb, W. H., M. Hite, and R. Eason 1966. Life history of the green lynx spider, Peucetia viridans (Araneida: Oxyopidae). J. Kans. Entomol. Soc. 39(2):259-67.
- Wratten, S. D. 1981. British trees and insects: the role of palatability. Amer. Natur. 118:916-919.

- Wright, R. J., J. W. VanDuyn, and J. R. Bradley, Jr. 1983. Seasonal phenology and biology of the southern corn billbug in eastern North Carolina. J. Georgia Entomol. Soc. 18:376-385.
- Yeargan, K. V. 1975. Factors influencing the aerial dispersal of spiders (Arachnida:Araneida). J. Kansas Entomol. Soc. 48:403-408.
- Yeargan, K. V., and C. D. Dondale 1974. The spider fauna of alfalfa fields in northern California. An. Entomol. Soc. Am. 67:681-682.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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