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Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

Intercropping to Create Local Refugia for Natural Enemies of Arthropod Pests: Flowers and Birds in Organic Agroecosystems

FINAL PROJECT REPORT (Year 2)

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PROJECT SUMMARY

In this two-year study we investigated the relationship between habitat structure produced by flower intercrops and the potential pest control functions provided by insectivorous birds and other beneficial species that are attracted to the intercrop (beneficial pollinators and entomophagous insects including predators and parasitoids). This work was motivated by preliminary findings on avian distributions on farms, and by observations of bird use of cut flower rows on two organic farms where we have monitored bird populations since the spring of 2000. We experimentally tested the hypothesis that sunflower rows in vegetable cropping systems may serve as predator-refugia. We predicted that fields including rows of flowers would have greater densities of insectivorous birds, and that greater foraging by insectivorous birds would be observed in fields with flower intercrops than fields without.

Sunflower treatment plots exhibited significantly greater mean densities of birds in the cropped fields than control plots ($F = 43.33$, $p < 0.001$). Those plots having just 1 sunflower row per acre exhibited significantly greater mean densities of birds than control plots in both years. Foraging observations and time budget analysis indicated that the presence of sunflower rows significantly increased presence ($F = 57.51$, $p < 0.001$) and foraging activity ($F = 50.18$, $p < 0.001$) of insectivorous birds in vegetable or row-crops compared to control plots. Visual observations and gut content samples of birds captured after foraging in crop vegetation confirmed that economically important pest insects were consumed.

Beneficial insects were attracted to sunflower plants by the time they reached 6” in height and occurred in significantly greater numbers on sunflowers and adjacent crop vegetation than in crops without sunflowers both years. Those beneficial insects observed on sunflowers and nearby (< 5 m) crop vegetation included arthropod predators, parasitic wasps, and important pollinators representing 30 different families.

Our work will contribute to a better understanding of the effects of vegetative structure and crop species composition on farm-bird community structure, with more general applications to implementation of environmentally sensitive agriculture.

INTRODUCTION

Innovative crop protection, through enhancement of predator-prey relationships characteristic of natural systems, has a pivotal role to play in the evolution of agriculture towards environmentally sustainable systems (Atkinson and McKinlay 1997). Methodologies that promote pest insect predators (e.g., birds, bats, wasps, beetles) on farms can augment non-chemical crop protection measures and provide beneficial consequences for conserving biological diversity in agricultural landscapes. Although the value of native insectivorous animals as predators in agroecosystems was once widely recognized and promoted by scientists and farmers, research on potentially beneficial species inhabiting agroecosystems was largely abandoned in 20th Century North America due to the pervasive utilization of pesticide technologies. As the agricultural industry swings back toward lower input, more environmentally sustainable systems (e.g., organic farming, natural systems agriculture; Colby 1990) to lessen its destructive impacts on human health (www.epa.gov/pesticides/whatis.htm updated October 19, 1999, www.epa.gov/pesticides/citizens/riskassess.htm updated November 17, 1999) and ecosystem functions (Altieri 1994), research focused on designing farming systems that emulate more complex ecosystems is urgently needed. Moreover, just as natural ecosystem functions and species composition reflect local biotic and abiotic conditions, so must efficient and sustainable agro-ecosystems (Soule and Piper 1992). Thus, research on sustainable and ecologically sophisticated agriculture must address designs appropriate for local conditions and sets of species, in addition to general principles of agroecosystem function and management (Lewis et al. 1997).

Biological control by natural enemies has been the most successful and promising alternative to unilateral reliance on chemical pesticides (Hoy 1992, Zalom et al. 1992), and is considered to be the 'backbone' of integrated pest management schemes (Rosen et al. 1996). The economic value of biological control methods included in integrated pest management (IPM) programs may be considerable over long time periods. For example, a study of citrus production in the San Joaquin Valley indicated substantial savings of pesticide and energy costs could be realized by growers utilizing IPM methodologies (Flint 1992). Biological control methods that promote pest insect predators for non-chemical crop protection, by their nature, also contribute to conservation of biological diversity in agricultural landscapes (The Soil Association 2000).

HABITAT MANAGEMENT FOR PREDATORS IN AGROECOSYSTEMS

Habitat management to enhance biological control refers to the establishment of environmental conditions amenable to natural enemies that increase and sustain their populations and improve their effectiveness in controlling pests (Pickett and Bugg 1998). Population processes such as colonization / dispersal and foraging movements of predators can be influenced by habitat modifications (Helenius 1998). On farms, such dynamics of natural enemy populations can be altered through management of within-field strips, cover crops, field margins, hedgerows, fencerows, windbreaks, irrigation and drainage ditches, and roadside margins. For example, Nentwig (1998) found that sown weed strips within cropped areas increased arthropod enemy abundance and activity in crops, via greater effective dispersal into the interior of expansive fields. Moreover, predation rates on pest species were higher near the sown strips. Others have recognized the potential importance of predator refugia within farmed areas for pest control but call for better understanding of the mechanisms underlying refugium design and function for managing natural enemies (Schoenig et al. 1998, Wratten et al. 1998).

Clearly, agroecological infrastructure (e.g., the landscape context and within-field structure of cropped areas) affects the maintenance and activity of predators at the scale of individual fields, and the conservation of predator diversity (richness and abundance) requires consideration of both favorable and unfavorable habitat aspects when designing predator-friendly agroecosystems (Booij and Noorlander 1992, Wratten et al. 1998). For example, studies of abundances and foraging activities of insectivorous birds in cropped systems (reviewed by Kirk et al. 1996) suggest that bird use of crops for foraging depends not only on food abundance, but also upon vegetation cover and microclimate in the field (Rodenhouse and Best 1994) and upon habitat composition in the surrounding landscape (Jones et al. ms). This study investigates effects of within-field habitat structure, microclimate, and food abundance upon the presence and foraging activity of insectivorous birds in cropping systems. These are all features under the direct control of farmers.

SPECIFIC STUDY OBJECTIVES

Farmer surveys conducted during the first year of a multi-year research program investigating the diversity and utilization of North-central Florida farmlands by birds demonstrated a great interest by organic producers in the potential impact birds have on insect populations in their cropping systems (Jacobson at al. 2003). They expressed interest in management recommendations designed to enhance the presence and foraging activities of insectivorous birds on their farms. Therefore based upon this interest we developed the following objectives for this study:

1. Analysis of census data collected in 2000 & 2001 indicated that the occurrence, densities, and foraging activities of birds in cropped fields are significantly higher in those having the greatest diversity of vegetation (polycultures vs. monocultures). These within cropped field density differences occurred even though the densities of birds in the non-cropped landscape surrounding these fields did not differ significantly (Jones et al. ms). Additionally, the occurrence, densities, and especially foraging activity of birds in polycultures were highest in those having sunflowers (*Helianthus annuus*) and other decorative flowers intercropped between vegetable rows. Analysis of birds by feeding guilds indicated that insectivorous bird densities were significantly higher in these polyculture systems (Jones et al. unpublished data). In this study we tested the hypothesis that sunflower rows included in a polyculture system increases the occurrence, densities, and foraging activities of insectivorous birds in cropped fields. Additionally, we attempted to determine the density of sunflower rows per acre needed to maximize bird presence and foraging activities while having the least impact upon yield per acre of other marketable crop production.
2. Foraging patterns, behavioral patterns / activity budgets of insectivorous bird species utilizing cropped treatment and control plots was documented to determine their actual use of these cropped areas. We also documented which insects were preyed upon by birds within the experimental plots via visual observation. We verified that birds were consuming economically important pest insects by capturing a sample of birds directly after foraging within cropped areas and administering an emetic to these individuals. Insects found within regurgitate samples were identified to order and family and compared to our insect surveys.
3. As a secondary objective, *Helianthus* spp. are listed in many extension fact sheets (Univ. of Florida Extension Circular 563, Univ. of Rhode Island Landscape Horticulture Factsheet, Univ. of Maine Coop Extension Bulletin # 7150) and other such publications (Long 1993, Starcher 1995, Turton 1998) as an excellent plant to attract beneficial insects (those known to be pollinators, to prey upon or parasitize agricultural insect pests) such as lacewings and ladybird beetles. Therefore we also performed a limited survey of the insect fauna found in our test plots to establish a partial listing and the relative occurrences of such beneficial arthropods in the test systems.

METHODS

RESEARCH SITE SELECTION

With the help of the director of the Florida Organic Growers Association, Marty Mesh, growers were identified in north-central Florida during the fall of 1999 and permission was obtained to conduct research activities on their properties during the course of our multi-year program. All participating farms were under certified organic management as designated by the

Florida Organic Growers Association (Florida Certified Organic Growers and Consumers, Inc., PO Box 12311 Gainesville, FL 32604,) and most are now USDA organic certified.

CROPPED-FIELD BIRD REFUGIA

Five of the ten certified organic growers that have participated in our research program thus far were asked to incorporate rows of multi-branched open-pollinating varieties of sunflowers into their cropped acreage at the earliest planting dates during their spring – summer planting seasons of 2002 and 2003. These multi-branched sunflowers have been observed to provide foraging, roosting, and even nesting micro-habitat for many species of insectivorous birds in two organic farms that already incorporate them extensively (Jones et al. unpublished data). A total of 18 ten-acre blocks were chosen for the study, eight of which received a sunflower row treatment while the other 10 served as controls within the participating farms. Sunflower rows consisted of 1m-wide rows of plants at a density of 1 plant per square foot and were interspersed between, and parallel with, production rows (Figure 1). Vegetable crops grown in the experimental blocks chosen for the study included polycultures of kale, collard greens, yellow and zucchini squash, tomatoes, green beans, cucumbers, and sweet corn. Only two of the blocks were fields dedicated to a single crop type (sweet corn).

A randomized block design was applied to the ten-acre plots, with sunflower row treatments at varying densities of 0, 1, or 2 rows per acre. Sunflower rows were maintained throughout the growing season as other crops were planted, harvested, and rotated through the acreage of each farm's production area. Treatment blocks were assigned different treatments during the second field season.

BIRD COMMUNITY STRUCTURE

Birds were censused and their foraging activities noted throughout the growing period between 1 April – 15 June in 2002 and 2003. Species occurrence, abundance, and foraging activity were noted during the study periods and compared to data collected during the past two years (2000 and 2001) at these same farm sites (Jones et al. unpublished data). Birds were sampled at each farm site utilizing standard point count methods, as described by Bibby et al. (1992) and Freemark and Rogers (1995). Sampling points were established at each experimental plot at field boundaries to allow comparison of the relative levels of bird activity within cropped and non-cropped landscape elements in these areas. Census points were located at least 100 m from each other when occurring within the same farm management unit. Each census point was surveyed six times between first planting and final harvesting dates at each farm site. The order and time of visitation for each point within the farms were reversed upon each subsequent census session at each farm. Census survey data yielded the response variables of point and farm species diversity and relative abundance of birds occurring in or near (within 50m) experimental plots.

Point counts were conducted between dawn and 10:00 hrs on fair weather days. All birds seen or heard within a 50 m fixed-radius from each census point during a ten-minute period were recorded. Registrations were recorded and mapped such that data was separated into 180 ^{O} semi-circles consisting of the cropped field and the uncropped area. Observations began 2-3 minutes after observers arrived at each point count station. Birds flying over sample areas were excluded, except swallows or martins if they were feeding on aerial invertebrates directly over crop vegetation (see Boutin et al. 1999). Utilizing mapping data sheets (marking exact locations of individuals and their movements) minimized duplicate records. Univariate analyses were performed to compare bird densities within and near (< 50 m) cropped fields before and after sunflower establishment in each farm and to determine sunflower row treatment effects upon bird response variables among experimental plots for the study (Zar 1999).

FORAGING SURVEYS

Observations of foraging behavior were made during six one-hour scan sampling sessions (Martin and Bateson 1993) at each treatment plot spread over the study period. Avian species observed to forage in crop vegetation were noted and those exhibiting greatest potential as insect pest predators in cropping systems were identified. An attempt was made to visually identify those insects being consumed by birds during foraging observation and census sessions. Use of sunflower plants by foraging species were noted and these substrates assessed for their effectiveness in enhancing foraging activity in surrounding crop vegetation. Univariate analysis was performed to compare differences in mean numbers of birds and amount of foraging activity among treatment plots (Zar 1999). Regression analysis was utilized to examine the relationship between foraging activity with size of sunflower plants during the growing period (Zar 1999).

GUT CONTENT SURVEYS

An attempt was made to gather detailed knowledge of the insects preyed upon by insectivorous birds within the test plots through gut content analysis. Birds were captured utilizing mist-netting techniques within treatment plots 1 hour after foraging activities were observed to commence. A partial sample of each bird's stomach contents were collected via a non-lethal forced regurgitation method as described by Prys-Jones et al. (1974). After capture, birds were orally administered an emetic consisting of $0.1 cm^3$ of 1% solution of antimony potassium tartrate per 10 g of body mass, and placed in a darkened holding cage lined with wax paper. Within 2 – 3 minutes, most birds regurgitated pellets of partially digested insects which were then collected and preserved for identification. Birds were then released at point of capture after a short rest period and an examination for any signs of stress. Samples obtained in this way have been found to compare well to total crop and stomach contents of collected birds (Rosenberg and Cooper 1990).

INSECT SURVEYS

Insects were sampled a minimum of three times in ten randomly chosen $1 m^3$ quadrates within the sunflower rows, and in ten randomly chosen locations a minimum of 10m distant from the sunflower rows within the crop vegetation at each ten-acre treatment site during the 2002 growing season. During 2003, insects were sampled within sunflower rows and in crop vegetation 1m and 10m distant from the sunflower rows. Insects were sampled utilizing a standard scouting technique in each quadrate (after Morris 1960, Southwood 1978). Insects observed were identified to family level and relative abundances noted. A simple assessment was made as to the occurrence and abundance of those insects considered beneficial in the systems as described by Henn et al. (1997) and the Univ. of Florida Coop. Ext. Service Insect Identification Sheets SPSET 5 (1997). Univariate analysis was used to compare the species diversity and relative density of beneficial insects found upon sunflower plants and crop vegetation during the two growing periods (Zar 1999).

RESULTS

Species Occurrence and Densities

An impressive list of bird species was observed on the organic farms participating in our overall research program over the past four survey years. A total of 68 species have been observed utilizing cropped fields or the bordering habitats (within 50 m) of these fields (Table 1). This diversity of species in the agricultural landscape of North-central Florida compares favorably with the current species checklist for Alachua County (within which all of our census points are located) and those species noted in the two Breeding Bird Survey routes (BBS routes # 25013 and #25113) located in the county. Our cumulative list represents 75 % of those resident and migratory landbird species known to breed in the Alachua County (Alachua Audubon Society 2001) and nearly all of those species noted in the most recent surveys along the two BBS routes that had been monitored in the county (USGS 2001a, USGS 2001b). Of the 68 species observed within the organic systems, 62 species (91%) were observed in the matrix surrounding cropped fields while 49 species (72%) were observed in the cropped fields themselves, five of which were only observed within these fields.

Mean densities of birds found in or near cropped fields varied considerably between census points, with significantly greater densities of birds occurring in each field’s border habitat. This is consistent with survey data collected in the two previous years at these same sites (Jones et al. ms). In the two previous years, there was no correlation between bird densities in the field borders and the vegetation characteristics of the cropped field. Avian occurrence and abundance in field borders varied significantly from site to site being greatly influenced by the composition of the border habitat and surrounding landscape type (Jones et al. ms). Mean densities of birds occurring in the 18 cropped fields varied significantly ($F = 2.74$, $p = 0.04$) from year to year (2.94 birds/ha in 2003, 3.31 birds/ha in 2002, 4.32 birds/ha in 2001, and 1.78 birds/ha in 2000). While mean densities of birds occurring in cropped areas were greater in the 2001 growing season before this experiment began, higher densities of birds in cropped fields during this year may have been a result of weather conditions. This region of Florida was experiencing a severe drought that may have made irrigated cropped areas generally more attractive habitat during the 2001 bird breeding season.

During the experiment, cropped areas with sunflower treatments exhibited significantly greater mean densities of birds than did control plots ($F = 43.33$, $p< 0.001$; Figure 2). This difference between sunflower and control plots was significantly greater in 2003 (MANOVA Year x treatment $F = 4.41$, $p = 0.013$). A significant difference in mean densities of birds occurring in cropped areas was not seen between these same plots in the previous two years of our research program (2000: $F = .843$, $p = 0.436$; 2001: $F = 1.41$, $p = 0.254$). Those plots having just 1 sunflower row per acre exhibited significantly greater mean densities of birds than control plots in both years (2002: $t = -2.63$, $p = 0.01$; 2003: $t = - 9.27$, $p < 0.001$). While cropped fields with 2 sunflower rows per acre exhibited greater mean density of birds than those with 1 row per acre in both years, this increase was significantly greater only in 2003 ($t = - 3.34$, $p = 0.004$; Figure 2).

Foraging Behavior

Over the past three years of our research program numerous species have been observed to actually forage for insects upon crop vegetation (see Table 1). Those species most often observed to forage in crops for insects include Northern Cardinals, Blue Grosbeaks, Northern

Mockingbirds, Eastern Bluebirds, and Indigo Buntings (Jones et al. ms). Foraging observations during the two growing seasons of this study indicated that the presence of sunflower rows significantly increased the presence and activity of insectivorous birds in vegetable or row-crops compared to control plots. Mean number of individual birds foraging in cropped areas was significantly greater in those plots with sunflower treatments ($F = 57.51$, $p < 0.001$; Figure 3). Mean foraging activity per hour in cropped areas was also significantly greater in those plots with sunflower treatments ($F = 50.18$, $p < 0.001$; Figure 4). This difference in foraging activity was consistent each year as treatment plots were rotated among the 18 experimental plots. Birds were found to be attracted to and utilize sunflower plants as perches by the time they were 24" tall. As sunflowers increased in stature, birds were observed to increasingly utilize sunflower plants as cover and perch sites from which they would forage into crop vegetation (Figure 5).

Birds observed to forage in crop vegetation were seen to consume numerous lepidopteran larvae as well as grasshoppers and beetles. These insects included Green Stink Bugs (*Acrosternum hilare*), Imported Cabbageworm (*Pieris rapae* - Linnaeus), and numerous Dipterans (Figure 6). Insects were taken directly from crop vegetation and either consumed on the spot or carried off into nearby field border habitat to presumably be consumed there or fed to young. A total of twenty birds representing the three species most commonly observed to forage for insects in crop vegetation (10 Northern Cardinals, 3 Blue Grosbeaks, 6 Indigo Buntings, and 1 Summer Tanager) were captured after foraging in crop vegetation and an attempt was made to procure gut samples. Gut content samples obtained from twelve of these captured birds confirmed that economically important pest insects, such as leaf-chewing caterpillars and grasshoppers, were consumed (Figures 7 & 8).

Beneficial Insect Occurrence

Beneficial insects were found to be attracted to sunflower plants by the time they reached 6" in height (Figure 9). Those beneficial insects observed on sunflowers and nearby crop vegetation (within 1m of sunflowers) included arthropod predators, parasitic wasps, and important pollinators representing 30 different families (Table 2). The most commonly occurring beneficial insects observed on sunflowers were Big-eyed Bugs (*Geocoris* ssp.), Honey Bees (Apis mellifera), Green Lynx Spiders (*Peucetia viridans*), Ants (Formicidae), and Sphecid Wasps (Sphecidae). The most commonly occurring beneficial insects observed on nearby crop vegetation were Green Lynx Spiders (*Peucetia viridans*), Lady Beetles (Coccinellidae), Big-eyed Bugs (*Geocoris* ssp.), Predatory Stink Bugs (Pentatomidae), and Assassin Bugs (Reduviidae). The relative occurrence of beneficial insects was significantly greater on sunflower vegetation than on crop vegetation in both 2002 ($F = 11.78$, $p = 0.003$; Figure 10) and 2003 ($F = 12.94$, $p = 0.002$; Figure 11). However, in 2003 when we censused and compared insects on crop vegetation directly adjacent to sunflowers (within 1m) and then 10 meters distant, we found the relative occurrence of beneficial insects did not significantly differ between sunflower and the adjacent crop vegetation ($F = 2.29$, $p = 0.144$; Figure 11).

DISCUSSION

Avian Abundance and Foraging Activity

Intrinsic habitat qualities such as food resources or shelter availability play important roles in habitat selection by birds (Bairlein 1983, Martin and Karr 1986, Moore et al. 1995). Habitat complexity resulting from a mix of different plant species, percentages of vegetative cover and variations in the size, distribution, and juxtaposition of plant assemblages will influence the local diversity of bird species (James 1971).

In this study we tested the hypothesis that cropped fields with sunflower rows incorporated into the cropping system would exhibit greater bird densities. Our results support this hypothesis. Those fields with even one row of sunflowers per acre exhibited significantly greater bird densities than those without, regardless of crop type or crop diversity. While an additional increase in density was seen with another row of sunflowers per acre, it appears that a single row may be enough to make cropped areas significantly more attractive for bird use. Therefore the addition of a single sunflower row per acre may provide the added structural vegetation to make a cropped field attractive for bird use in those systems were their presence can provide a benefit.

Previous studies suggest foraging activities of insectivorous birds in cropped systems depends upon vegetation cover and microclimate in the field (Rodenhouse and Best 1994 and reviewed by Kirk et al. 1996). In this study we also tested the hypothesis that foraging activity would be increased in crop vegetation with the presence of sunflower rows. Results of our foraging observations support this hypothesis. Birds were found to begin to utilize sunflower vegetation as soon as the plants were able to support them as a perch and begin to provide some cover (Figure 12). Once sunflowers reached a height of at least 24", birds were observed to fly in to the fields and first land on the sunflowers before venturing into nearby crop vegetation. Birds flew first to sunflowers, perched and surveyed crop vegetation for prey, and then dropped down to capture prey from their sunflower perch. As the sunflower plants grew taller, birds increasingly utilized them as cover to travel to and within the rows, similar to utilizing a hedgerow (Figure 13). Several studies have confirmed the strong relationship between hedgerow presence and composition, and avian presence and community structure in agricultural landscapes (see O' Connor 1984, MacDonald and Johnson 1995). Therefore in those fields in which birds may provide a benefit as insect predators, the addition of sunflowers into the cropping system may be an effective, inexpensive, and temporary habitat modification.

In this study we observed birds actively pursuing and consuming economically important pest insects gleaned from crop vegetation. The value of utilizing naturally occurring enemies cannot be overemphasized within organic farming systems and IPM programs (Rosen et al. 1996). Insectivorous birds are naturally occurring components of agroecosystems whose feeding activities in and around cropped areas may be of great economic value. Birds are both mobile enough to recruit readily to high-density food patches in their relatively large home ranges, and are capable of complex prey-switching and specialization behaviors (McFarlane 1976, Kirk et al. 1996). Due to these characteristics, birds are potentially important components of biological control regimes provided they increase the natural mortality of agricultural arthropod pests without adversely affecting other natural enemies and the crops themselves (McFarlane 1976, Kirk et al. 1996).

As pest predators, birds may provide both numerical and functional responses to prey availability over short time periods and large areas (Holling 1988, Dahlston et al. 1990, Holmes 1990) – potentially stabilizing pest communities in agroecosystems, augmenting the activities of other classes of predators with different characteristics (Price 1987, Rosen et al. 1996, Helenius 1998). Since birds responded to the presence of sunflower rows after they reached a certain height, timing of planting of these rows will be critical to maximize the benefit of attracted insect predators. Sunflower plantings should proceed that of other crop vegetation by several weeks to allow their establishment and potential attraction of beneficial predators before crops, and any associated pests, reach critical growth stages. Optimally, potential suppression of pest insects will occur if an adequate predator base is present before pests colonize crop vegetation and their populations grow to economically damaging levels (Price 1987, Rosen et al. 1996, Helenius 1998).

Several bird species are known to cause considerable damage to certain crops, especially flocking species such as Red-winged Blackbirds (*Agelaius phoeniceus*) and Cedar Waxwings (*Bombycilla cedrorum*). During our 4 years of observations of birds in cropping systems we observed very little crop damage by birds. During the spring growing season of 2001, North-central Florida experienced severe drought conditions. In this season we observed watermelon damage cause by American Crows (*Corvus brachyrhyncos*) presumably to obtain water (Figure 14). In all four years 2000 – 2003 we also observed a limited amount of strawberry damage caused by Northern Mockingbirds (*Mimus polyglottos*; Figure 15). During this study participating farmers reported that they did not experience any increase in bird damage due to attracting more birds into their cropping systems with sunflower plantings. We did not observe any of the three most problematic species mentioned above utilizing sunflowers (blackbirds, crows, or waxwings) or being attracted to plots with sunflower rows over the study period. Most bird damage to crops in the U.S. occurs to grain and small fruit crops and appears to be worse in certain regional locations, certain cropping system designs, and in crops bred for very early or late season harvests (reviewed by Rodenhouse et al. 1995). In a recent survey of Florida farmers, bird damage to crops was reported by 32.9% of the survey participants primarily indicating damage to watermelon or corn by crows (Jacobson et al. 2003). However only 11.8% reported the need to utilize bird control methods to limit damage. In some cases proper "farmscaping" cannot only increase the presence of beneficial organisms, but may reduce the presence or abundance of problematic species in cropping systems as well. Farmscaping is defined as a whole-farm, ecological approach to pest management through selective placement of hedgerows, insectary plants, cover crops, and water reservoirs to attract and support populations of beneficial organisms such as insects, bats, and birds of prey (http://attra.ncat.org/attra-pub/PDF/farmscaping.pdf). Research in farmscaping to maximize beneficial organisms and limit pests is ongoing to identify and develop such management strategies (Pickett and Bugg 1998).

BENEFICIAL INSECT OCCURRENCE

Our scouting efforts revealed that sunflowers did indeed attract and play host to numerous beneficial insects as has been described in numerous publications. Sunflower plants were found to attract predaceous insects almost immediately after establishment. Parasitoids and pollinators were attracted as soon as these plants began to produce flowers. These same beneficial insects were found to also occur on nearby crop vegetation presumably after being attracted to the sunflowers and then moving onto adjacent crop vegetation. It has been found in several studies that providing predator refugia within cropping systems via strip crops or uncultivated corridors can result in the migration of predatory insects into adjacent crops (see Johanowicz and Mitchell 2000, Mensah 1999, Nentwig 1998, Schoenig et al. 1998, Wratten et al. 1998, Rodenhouse et al. 1992). In the 2003 growing season we modified our sampling methodology in an attempt to determine whether beneficials attracted to the sunflowers were indeed moving out from the sunflowers into adjacent crop vegetation. Results indicated that crop vegetation 10 m distant from sunflowers harbored significantly fewer beneficial insects than did that within 1 m. Moreover, crop vegetation exhibited nearly the same abundance and diversity of beneficial insects as did the sunflowers themselves. Therefore we believe that these insects attracted to the sunflowers were indeed moving from them into crop vegetation. Further study is required to determine the actual distances key beneficial insects actually move from sunflowers and the effective distance into crops these insects impact pests.

IMPRESSIONS OF PARTICIPATING GROWERS

Growers unanimously indicated that adding sunflower rows into their cropping plans did not interfere with their normal management operations. In most cases participants were able to incorporate sunflower rows in space that would not have been planted with other crops and therefore did not result in reducing yields per acre than would have otherwise been obtained. All growers indicated that they noticed an increase in bird presence and activity in those areas with sunflowers compared to control plots. As was noted above, they reported having experienced no unusual or increase in crop damage by this increased bird activity. All of the participants indicated that they felt that there was a positive impact on pest control due to the presence of sunflower rows but were unable to quantify the impact. The quantification of pest reduction due to birds and/or beneficial insects attracted by sunflower intercrops will be a focus of future work we intend to perform. Two of the five growers participating in the study reported they were able to sell blooms at local farm markets and generate some additional income having done so. Several growers commented that they thought it would be possible to generate income with sunflower plantings if they decided to market and establish a client base for the this produce. At the conclusion of the study 4 of 5 participants indicated they would continuing to intercrop sunflower strips as part of their regular cropping scheme.

CONCLUSION

Bird populations and avian community structure are known to respond differently to the distribution of cropped and non-cropped landscape elements and the distribution, relative cover classes, and juxtaposition of agricultural landscape elements in agroecosystems (Freemark et al. 1993, Rodenhouse et al. 1993). The addition of structurally diverse vegetation strips within cropped fields appears to attract and provide cover for birds utilizing adjacent non-crop habitats. In so doing the probability that these highly insectivorous animals may provide an economic benefit to producers is greatly increased. In return the creation of suitable habitat within cropping systems may aid in the conservation of all avian species within agroecosystems. Within the discipline of conservation biology there is increasing recognition that protected reserves alone will not be sufficient to conserve biodiversity in the long term, therefore methods of integrating conservation and productive use must be achieved (Hobbs and Norton 1996). The long-term goal of our research is to integrate the needs of avian populations with sustainable agriculture via the identification of cropping systems that best provide suitable habitat and developing enhancement protocols for agroecosystem environments. This study contributes to a better understanding of the effects of vegetative structure and crop species composition on farm-bird community structure, with more general applications to implementation of environmentally sensitive agriculture.

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Table 1. Species observed within cropped fields or within 50 m of cropped fields of organic farmlands in North-central Florida during the breeding seasons 1 April through 30 June 2000 - 2003. The 10 most commonly observed insect eating species are bold faced. Those species observed foraging within crop vegetation are indicated with an asterisk.

Common Name	Forager	Scientific Name
Acadian Flycatcher		*Empidonax virescens*
American Crow	*	*Corvus brachyrhynchos*
American Goldfinch	*	*Carduelis tristis*
American Kestrel		*Falco sparverius*
American Redstart	*	*Setophaga ruticilla*
Barred Owl		*Strix varia*
Bay-breasted Warbler	*	*Dendroica castanea*
Blackpoll Warbler	*	*Dendroica striata*
Blue-gray Gnatcatcher		*Polioptila caerulea*
Blue-headed Vireo		*Vireo solitarius*
Blue Grosbeak	*	*Guiraca caerulea*
Blue Jay	*	*Cyanocitta cristata*
Bobolink	*	*Dolichonyx oryzivorus*
Brown-headed Cowbird		*Molothrus ater*
Brown Thrasher	*	*Toxostoma rufum*
Boat-tailed Grackle	*	*Quiscalus major*
Cape May Warbler		*Dendroica tigrina*
Carolina Chickadee	*	*Parus carolinensis*
Cattle Egret	*	*Bubulcus ibis*
Carolina Wren	*	*Thryothorus ludovicianus*
Cedar Waxwing		*Bombycilla cedrorum*
Chimney Swift		*Chaetura pelagica*
Common Grackle		*Quiscalus quiscula*
Common Ground Dove	*	*Columbina passerina*
Common Yellowthroat	*	*Geothlypis trichas*
Downy Woodpecker		*Picoides pubescens*
Eastern Bluebird	*	*Sialia sialis*
Eastern Kingbird	*	*Tyrannus tyrannus*
Eastern Meadowlark	*	*Sturnella magna*
Eastern Towhee		*Pipilo erythrophthalmus*
Eastern Tufted Titmouse		*Parus bicolor*
European Starling		*Sturnus vulgaris*
Eastern Wood-pewee		*Contopus virens*
Fish Crow		*Corvus ossifragus*
Gray Catbird	*	*Dumetella carolinensis*
Great Crested Flycatcher	*	*Myiarchus crinitus*
Great Horned Owl		*Bubo virginianus*
Green Heron		*Butorides striatus*
House Finch	*	*Carpodacus mexicanus*
Indigo Bunting	*	*Passerina cyanea*
Loggerhead Shrike	*	*Lanius ludovicianus*
Mississippi Kite		*Ictinia mississippiensis*
Mourning Dove	*	*Zenaida macroura*
Northern Bobwhite	*	*Colinus virginianus*
Northern Cardinal	*	*Cardinalis cardinalis*
Northern Flicker		*Colaptes auratus*

Northern Mockingbird	*	*Mimus polyglottos*
Northern Parula	*	*Parula americana*
Orchard Oriole	*	*Icterus spurius*
Ovenbird	*	*Seiurus aurocapillus*
Pine Warbler		*Dendroica pinus*
Pileated Woodpecker		*Dryocopus pileatus*
Purple Martin	*	*Progne subis*
Red-bellied Woodpecker	*	*Melanerpes carolinus*
Red-eyed Vireo		*Vireo olivaceus*
Red-headed Woodpecker	*	*Melanerpes erythrocephalus*
Red-shouldered Hawk	*	*Buteo lineatus*
Rudy-throated Hummingbird	*	*Archilochus colubris*
Red-winged Blackbird	*	*Agelaius phoeniceus*
Rough-winged Swallow		*Stelgidopteryx ruficollis*
Sandhill Crane	*	*Grus canadensis*
Summer Tanager	*	*Piranga rubra*
Western Palm Warbler	*	*Dendroica palmarum*
White-eyed Vireo		*Vireo griseus*
White Ibis		*Eudocimus albus*
Wild Turkey	*	*Meleagris gallopavo*
Yellow-billed Cuckoo	*	*Coccyzus americanus*
Yellow-shafted Flicker		*Colaptes auratus*
Yellow-throated Vireo		*Vireo flavifrons*

Table 2. Beneficial insects that were observed to occur in randomly placed 1m scouting plots on sunflower and nearby crop vegetation (within 1m of sunflowers) during spring growing seasons 2002 and 2003. Beneficial insects included arthropod predators, parasitic wasps, and important pollinators representing 30 different families.

Family	Common Name	Benefit
Anthocoridae	Pirate Bugs	predator
Apidae	Honey Bees	pollinator
Asilidae	Robber Flies	predator
Cantharidae	Soldier Beetles	predator
Chrysididae	Cuckoo Wasps	predator
Coccinellidae	Lady Beetles	predator
Danaidae	Milkweed Butterflies	pollinator
Dermaptera	Earwigs	predator
Eulophidae	Eulophid Wasps	parasite
Formicidae	Ants	predator
Gelastocoridae	Big-eyed Bugs	predator
Halictidae	Green Metallic Bees	pollinator
Hesperiidae	Skippers	pollinator
Ichneumonidae	Parasitic Wasps	parasite
Lycaenidae	Gossamer-winged Butterflies	pollinator
Mordellidae	Tumbling Flower Beetles	predator
Mutillidae	Velvet-ants	predator
Mymaridae	Mymarid Wasps	parasite
Oxyopidae	Lynx Spiders	predator
Papilionoidae	Swallowtail Butterflies	pollinator
Pentatomidae	Predatory Stink Bugs	predator
Plutellidae	Diamond-backed Moths	pollinator
Reduviidae	Assassin Bugs	predator
Scarabaeidae	Scarab Beetles	predator
Sphecidae	Sphecid Wasps	parasite
Tenebrionidae	Darkling Beetles	predator
Thomisidae	Crab Spiders	predator
Tiphiidae	Tiphiid Wasps	parasite
Trichogrammatidae	Trichogrammatid Wasps	parasite
Vespidae	Vespid Wasps	parasite

Figure 1. Multi-branching sunflower varieties were planted at 1 or 2 rows per acre between vegetable rows to attract birds and beneficial insects into cropped fields. A row of sunflowers is shown here planted between rows of tomatoes.

Figure 2. Sunflower treatment plots exhibited significantly greater mean densities of birds in the cropped fields than control plots during the 2002 and 2003 spring growing seasons ($F = 43.33$, $p < 0.001$). Plots having just 1 sunflower row / acre exhibited significantly greater densities of birds than control plots in both years (2002: $t = -2.63$, $p = 0.01$; 2003: $t = -9.27$, $p < 0.001$). While cropped fields with 2 sunflower rows per acre exhibited greater mean density of birds than those with 1 row per acre in both years, this increase was significantly greater only in 2003 ($t = -3.34$, $p = 0.004$).

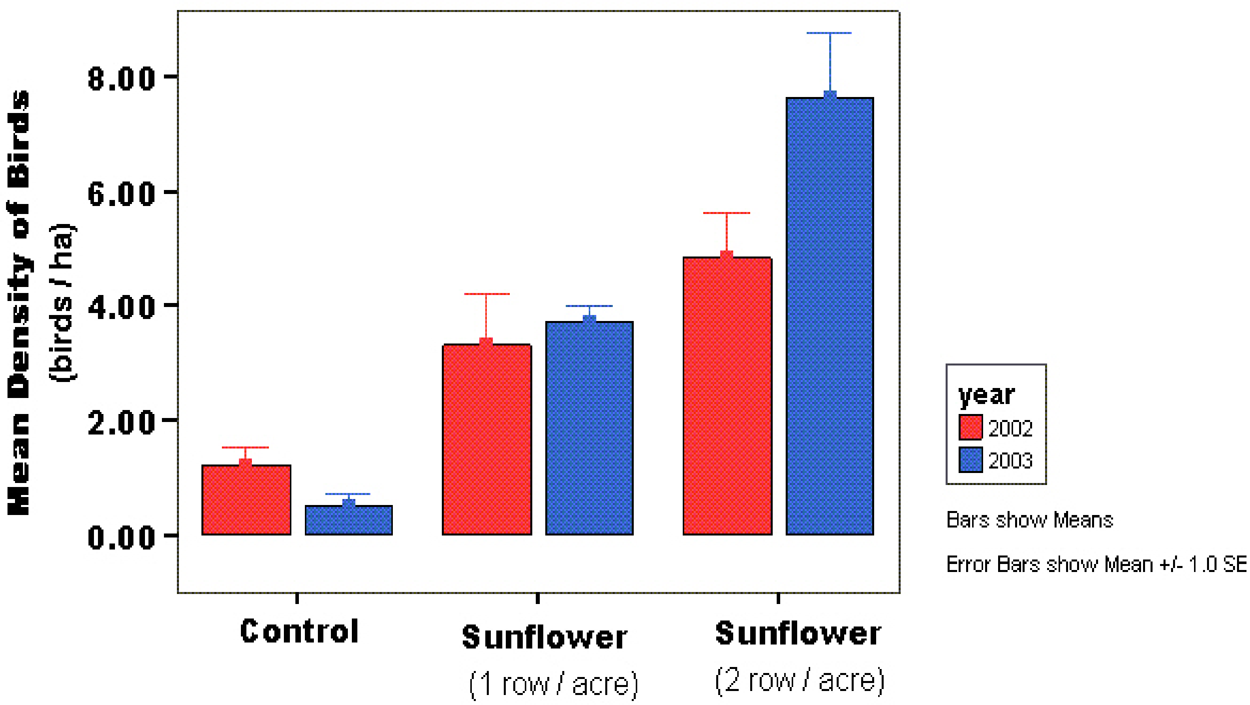

Figure 3. Mean number of individual birds foraging in cropped areas was significantly greater in those plots with sunflower treatments in both growing seasons 2002 and 2003 ($F = 57.51$, $p < 0.001$).

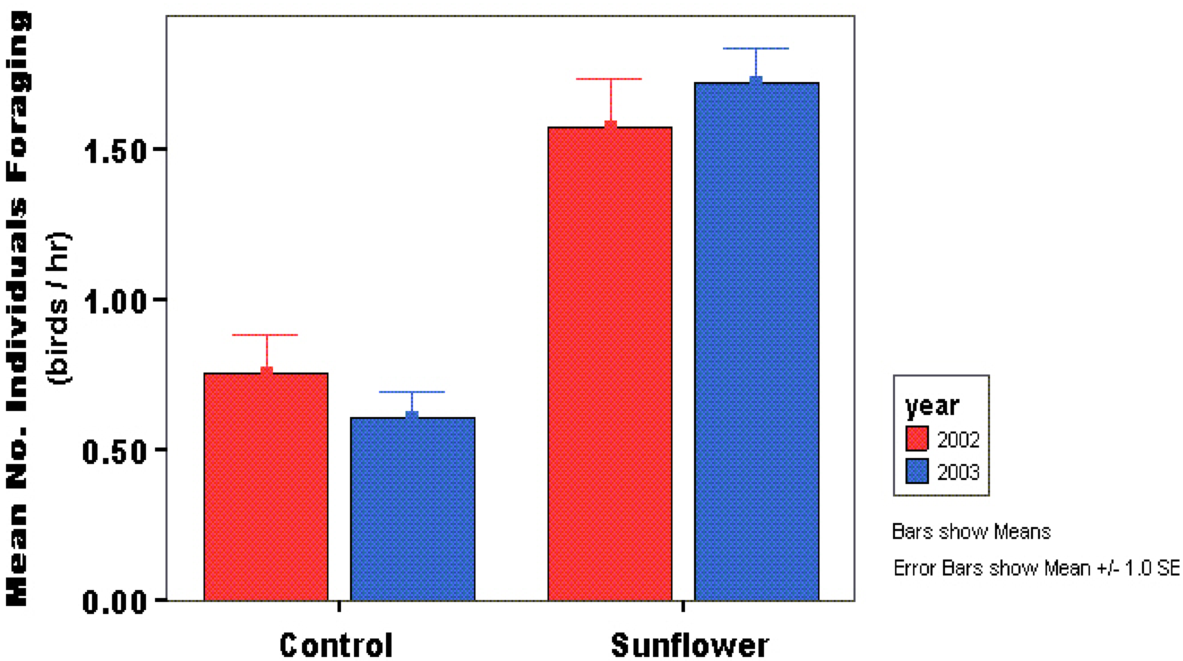

Figure 4. Mean foraging activity per hour in cropped areas was significantly greater in those plots with sunflower treatments in both growing seasons 2002 and 2003 ($F = 50.18$, $p < 0.001$).

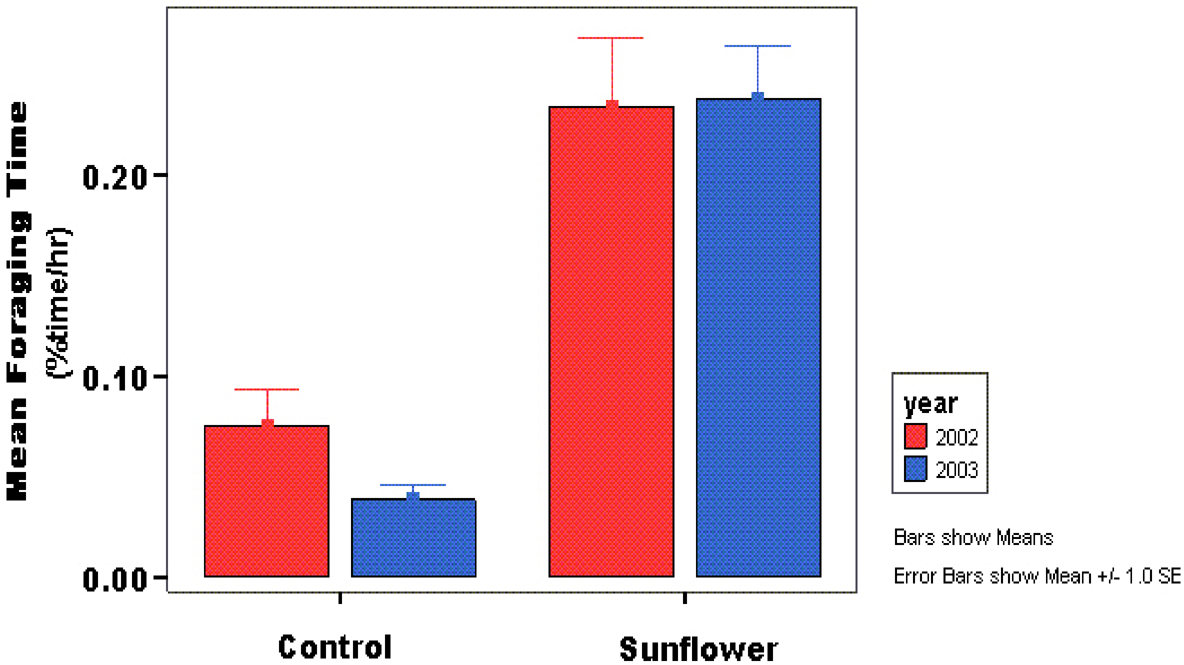

Figure 5. As sunflowers increased in stature, birds were observed to increasingly utilize sunflower plants as cover and perch sites from which they would forage into crop vegetation. An Eastern Kingbird (*Tyrannus tyrannus*) surveys crop vegetation from a sunflower perch looking for a tasty insect.

Figure 6. Birds foraging in crop vegetation were observed to consume numerous lepidopteran larvae as well as grasshoppers and beetles. Insects consumed by birds included Green Stink Bugs (*Acrosternum hilare*), Imported Cabbageworm (*Pieris rapae* - Linnaeus), and numerous Dipterans.

Figure 7. Gut content samples obtained from birds captured after foraging in crop vegetation confirmed that economically important pest insects were consumed such as leaf-chewing caterpillars. The respiratory organs (Malpighian tubules) and the intestinal tracts of numerous caterpillars were identifiable in most stomach samples.

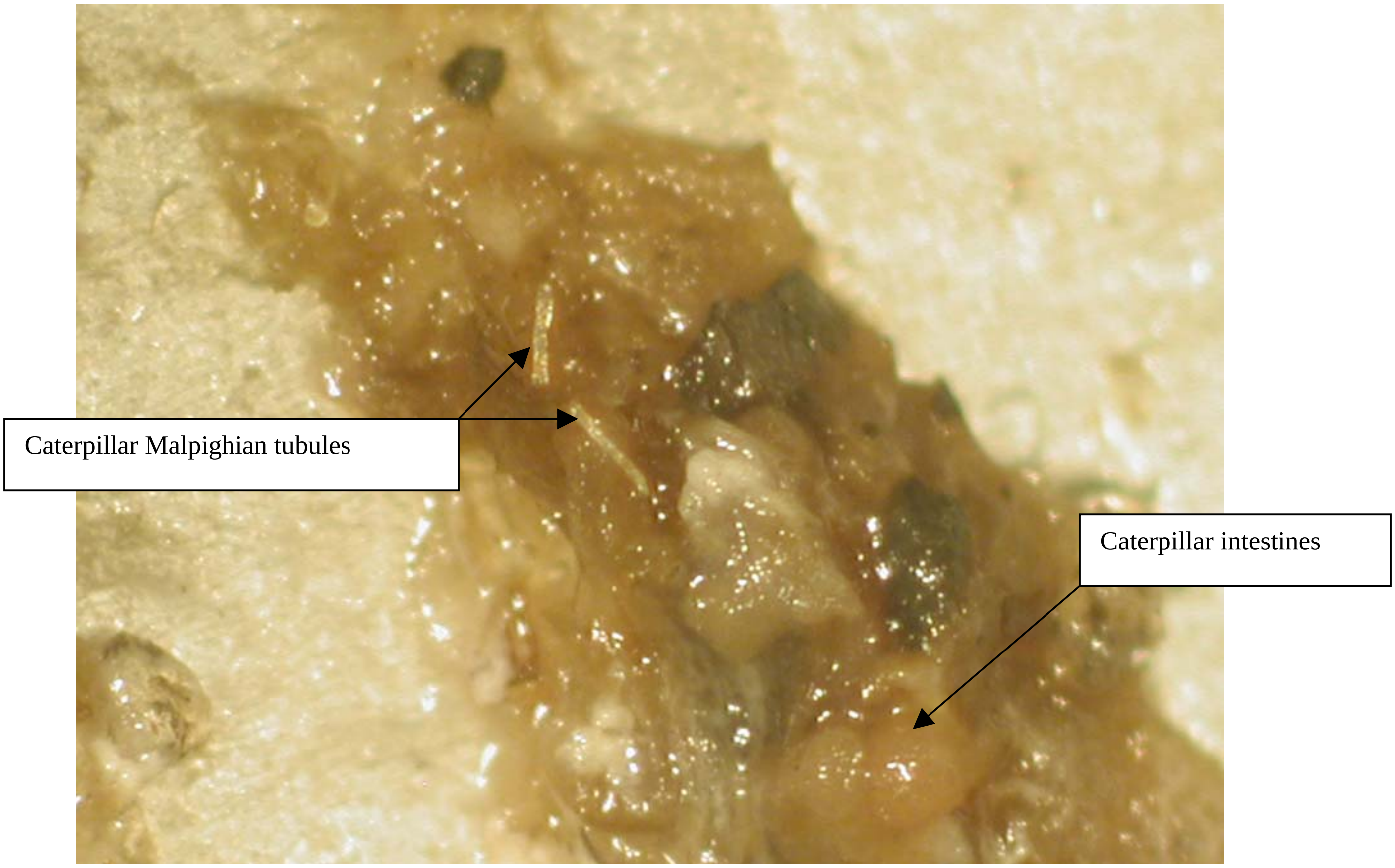

Figure 8. Gut content samples obtained from birds captured after foraging in crop vegetation confirmed that economically important pest insects were consumed such as grasshoppers. Pieces of body covering (exoskeleton) and leg segments of grasshoppers were found in many of these stomach samples.

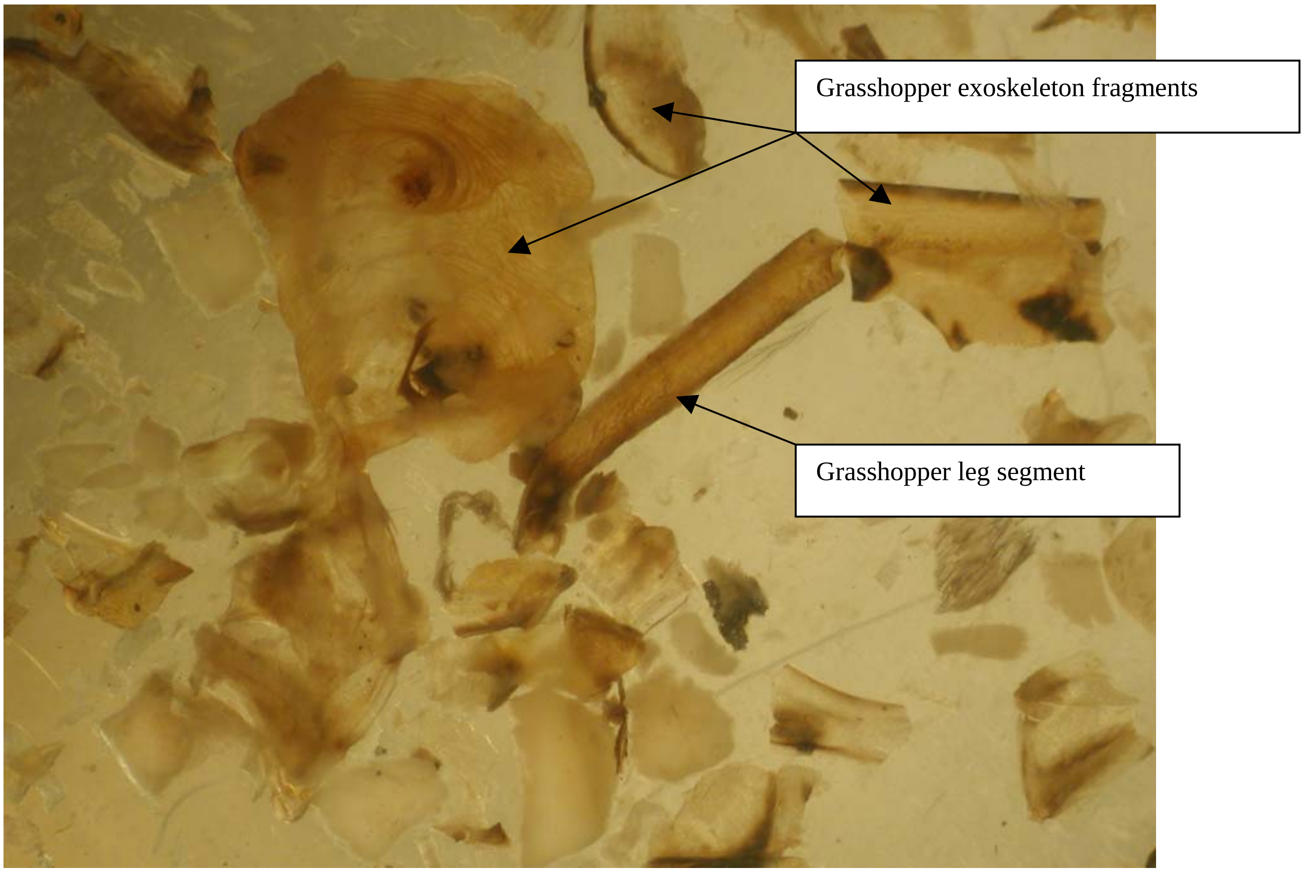

Figure 9. Beneficial insects were found to be attracted to sunflower plants by the time they reached 6” in height such as this Two-spotted Lady Beetle (*Adalia bipunctata*).

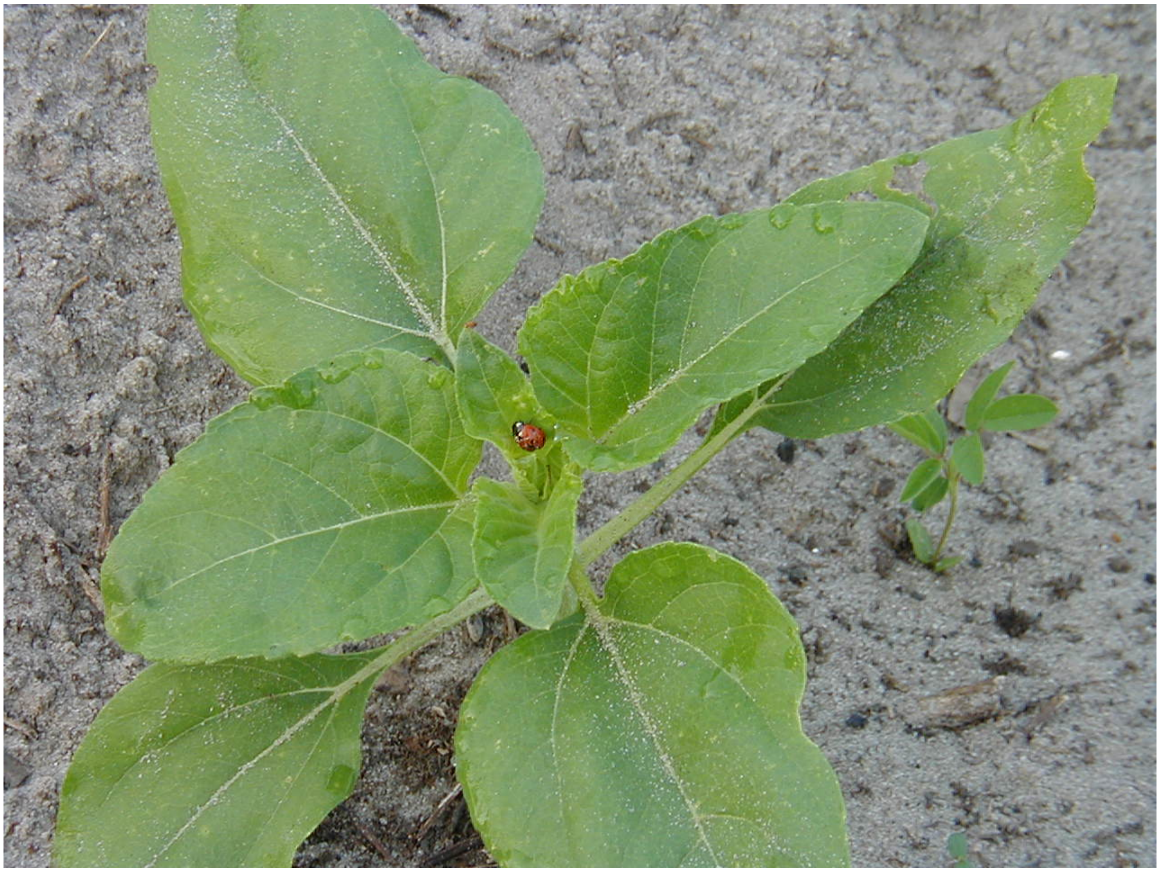

Figure 10. Relative occurrence of beneficial insects was significantly greater on sunflower vegetation than on crop vegetation during the 2002 growing season (F = 11.78, p = 0.003).

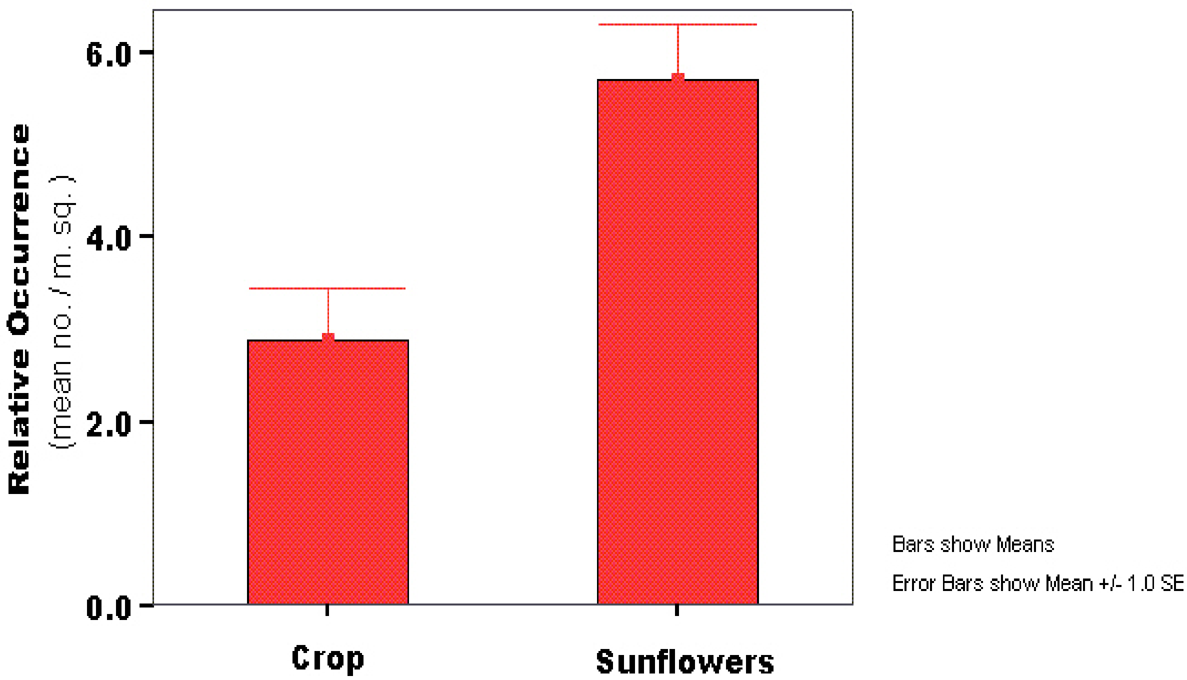

Figure 11. The relative occurrence of beneficial insects was significantly greater on sunflower vegetation than on crop vegetation more than 10 m distant from sunflowers in 2003 ($F = 12.94$, $p = 0.002$). Relative occurrence of beneficial insects on crop vegetation directly adjacent to sunflowers (within 1m) did not significantly differ from that found on the sunflower vegetation ($F = 2.29$, $p = 0.144$).

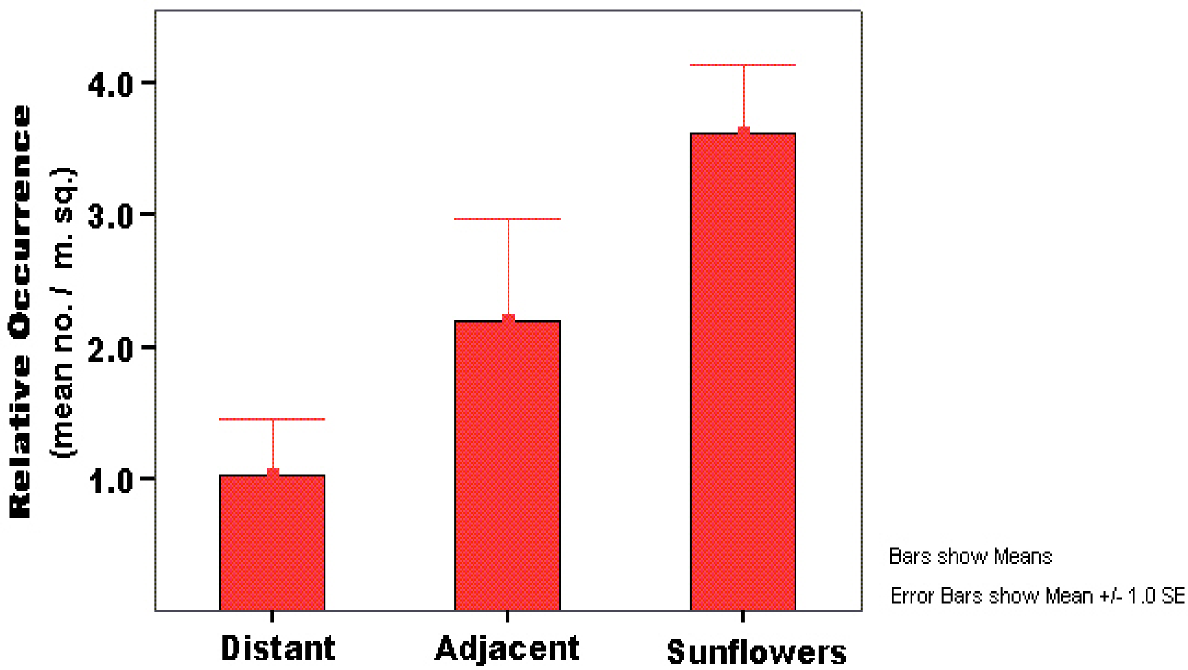

Figure 12. Birds were found to begin to utilize sunflower vegetation as soon as the plants were able to support them as a perch and begin to provide some cover. Once sunflowers reached a height of at least 24", birds were observed to fly into the fields and first land on the sunflowers before venturing into nearby crop vegetation. A Palm Warbler (*Dendroica palmarum*) is shown perched on a sunflower while foraging for insects in nearby rows of kale.

Figure 13. As the sunflower plants grew taller, birds increasingly utilized them as cover to travel to and within cropped fields similar to utilizing a hedgerow. A female Northern Cardinal (*Cardinalis cardinalis*) is shown perched on a sunflower after foraging for insects in nearby crop vegetation.

Figure 14. During the spring growing season of 2001, watermelon damage cause by American Crows (*Corvus brachyrhynchos*) was observed at several farm sites. During this spring growing season North-central Florida experienced severe drought conditions. This type of damage was caused by this species presumably in attempts to obtain drinking water.

Figure 15. During our 4 years of observations of birds in cropping systems (2000 – 2003) we observed a limited amount of strawberry damage caused by Northern Mockingbirds (*Mimus polyglottos*).