# THE EFFECTS OF ALTERNATIVE AND CONVENTIONAL MANAGEMENT SYSTEMS IN COTTON AGRICULTURE ON AVIAN AND ARTHROPOD POPULATIONS IN THE UPPER COASTAL PLAIN OF GEORGIA

by

SANDRA BLOOMFIELD CEDERBAUM

(Under the direction of Robert J. Cooper and John P. Carroll)

ABSTRACT

Significant agricultural advancements over the past 50 years have altered the landscape and negatively affected the avian populations associated with early successional habitat. Among the major agricultural crops in the Southeast, cotton is generally considered to provide the least suitable habitat for most early successional songbirds. Newer cropping systems such as use of conservation tillage and stripcover cropping offer hope for improving the value of cotton fields to songbirds. During 1999 and 2000, we examined the effects of stripcover planting, in conservation tillage, versus conventionally grown cotton, in both conventional and conservation tillage, on the avian and arthropod species composition and field usage in eastern-central Georgia. Stripcover fields had higher avian densities and detections, and arthropod biomass and relative abundance than both Conservation tillage and Conventional fields. Our findings suggest that both conservation tillage and stripcropping systems will improve conditions for birds in cotton, with stripcropped fields providing superior habitat.

INDEX WORDS: Birds, Cotton, Clover, Stripcover cropping, Alternative agriculture, Conservation tillage, Avian, Beneficial insects, Arthropods, Songbirds, Relay stripcover cropping

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This thesis is dedicated

to my parents,
ELEANOR AND BILL BLOOMFIELD,

although they may not always have understood my life choices,
they have never faltered in supporting them,

and

my friend and husband,
SANDY,

who still makes me smile.

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And finally, thanks to Dr. Jim Applegate for showing me many years ago, among other wonders of the avian world, that a "blue bird" was not necessarily a Bluebird.

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# INTRODUCTION

The state of Georgia and the southeastern U.S. have seen a significant decline in numerous avian species associated with early successional habitat over the past thirty years (Sauer et al. 2001). While early successional refers to habitats such as grassland, brush, and farmland, in the Southeast it exists primarily in young pine plantations and agricultural areas. Those avian species associated with this habitat guild have the strongest overall declining population trend in the U.S. (Sauer et al. 1995), which is primarily ascribed to the destruction of breeding grounds by intensive agricultural methods (Askins 1993) and conversion of early successional habitat to other land types. Agricultural practices such as tillage, planting, cultivation, and harvesting affect both adults and young through direct mortality and nest disturbance (Rodenhouse et al. 1995). Indirect effects resulting from these methods reduce food resources by changing the herbaceous and arthropod composition found in the fields. Most grassland species are migratory; therefore, the state of the wintering grounds in the southern U.S. and the tropics is also a concern, but few studies have addressed this portion of their lifecycle (Askins 1993). Some evidence has surfaced that implicates the winter grounds as a limiting factor for some species through high mortality or skewed sex ratios believed to be due to changes in the available food source (Askins 1993). Because of the changes in habitats in both the breeding and the wintering grounds, and the inter-relatedness of these portions of the annual cycle (Sherry and Holmes 1995) early successional species may be subject to increased overall pressure.

Of the current crops in production in the Southeast, wildlife biologists often consider cotton crops to provide the least desirable habitat for early successional avian species (Stoddard 1931), while at the same time cotton acreage in the Southeast has seen a resurgence (Luttrell 1994). During the latter half of the 20$^{th}$ century, changes in cotton management created a system with a heavy reliance on chemicals and field manipulations that is highly dependent on human intervention to maintain productivity (Smith et al. 1976, Luttrell 1994). Modern agriculture has created artificial ecosystems and advocate the use of plants that will provide an superior product through plant breeding, but often leave the crop vulnerable to pests (Smith et al. 1976). Research must turn to an enhanced ecological approach for a more stable system. In order to develop agroecological systems that will be accepted in the agricultural community, they must not reduce, but preferably increase farm profit (Rodenhouse et al. 1993). Sustainable farming systems which reduce human input, in the form of fertilizer, pesticides, herbicides, and cultivation, while creating a more stable agroecosystem, can also reduce costs for farmers (White and Wetzstein 1995) and allow for increased field diversity in insect, plant, and animal communities. Conservation tillage, intercropping, and relay cover cropping are a few of the methods being used in cotton to try to achieve this goal. In addition to reestablishing some structural diversity in the agricultural landscape, these practices allow for the reintroduction of diverse arthropod communities. Avian species benefit not only from the increase in prey, but there may also be an increase in nesting sites and cover for fledglings within the field, as well as a reduction in nest loss as a result of conservation tillage (Castrale 1985, Basore et al. 1986). With the limited availability of suitable nesting areas in the U.S. for early successional songbirds (Best et al. 1990, Rodenhouse et al. 1993, Rodenhouse et al. 1995), converting a common attribute of an agricultural landscape, such as cotton fields, to a productive resource for food and reproductive habitat would provide some of the factors necessary to increase survival and nesting success.

This research project evaluated the effects of stripcover cropping and other current cotton management systems on early successional avian and insect species and vegetative habitat structure of the fields. Specifically we examined and compared the avian density and vegetation structure, during winter, migration, and breeding periods, and summer insect community, between systems. Vegetation structure was analyzed to determine if correlations existed with avian field utilization.

# LITERATURE REVIEW

## Effects of Agriculture on Avian Populations

The overall population decline of early successional avian species in the U.S. and Great Britain is largely attributed to major changes in land use and agricultural practices (O'Connor and Shrubb 1986, Rodenhouse et al. 1993, Rodenhouse et al. 1995, Chamberlain and Fuller 2000). In the U.S. farmland in particular has declined tremendously, with a loss of 260 million acres since the early 1950's (National Agricultural Statistics Service 2001). This change is equivalent to 11% of the U.S. or roughly the southeastern U.S. from Virginia and Kentucky south to Florida and west to the Mississippi River. When farms were abandoned, the land was no longer maintained in an early successional state through cultivation, resulting in habitat loss for early successional species. In the Southeast much of this land is now in pine plantations, hardwood forests, or converted to urban landscapes. Although young plantations provide habitat for early successional species, the period is short lived and is followed by decades of unsuitability. Urban growth permanently alters the habitat by removing native vegetation and replacing it with an intensively managed inhospitable blanket of grass and pavement, while simultaneously inflating predatory pressure from domesticated animals. This conversion has resulted in population declines.

In addition to changes in land use, major changes in farm management have occurred as competition in world markets and technology created trends toward more intensive and specialized farming. The change from rather diverse small farms to large operations, often geared to the production of one or a few crops, has in general had a negative impact on farm wildlife (O'Connor and Shrubb 1986, Rodenhouse et al. 1993, Kershner and Bollinger 1996, Delisle and Savidge 1997, Potts 1997). Consolidation of fields to large monocultures removes structural diversity in the form of hedgerows, fallow fields, and damp depressions and is thought to lower species diversity and populations of the plant, seed, and arthropod communities within the field (Rodenhouse et al. 1993, Sotherton 1998). Reduced avian densities have been detected within cornfields compared with field borders, with field abundance decreasing logarithmically with increased field size (Best et al. 1990). Further, use of herbicides to control weed populations within agricultural fields has dramatically increased since the late 1940's (Potts 1997) and has changed the species structure of plant communities within fields (O'Connor and Shrubb 1986, Freemark and Boutin 1995 and citations within). The resulting simplified system indirectly affected avian populations through the removal of the "weeds" their insect prey required. The well-documented decline of the Grey Partridge (*Perdix perdix*) and many other European early successional species has been attributed to the herbicide-induced alterations in plant communities and the ensuing decimation of the arthropod community (Campbell et al. 1997, Potts 1997, Ewald and Aebischer 1998). Previous cultural controls for weediness, such as crop rotations, have since been abandoned, resulting in extended monocultures, spatially and temporally, in areas of previously diverse habitat (O'Connor and Shrubb 1986). Freemark and Kirk (2001) found a higher number of avian species associated with diverse habitat (hedgerow, pasture, farmstead) than intensified agriculture. The consequential effects of the change to large monocultures on reproductive success or survival of grassland passerines are largely unknown (Rodenhouse et al. 1995).

Increased field size was coupled with increased reliance on mechanization of farm labor (Rasmussen 1982), with direct effects on nesting bird populations (Rodenhouse and Best 1983, Castrale 1985) due to the widespread use of conventional or clean-tillage farming. Conventional tillage traditionally employs the use of a moldboard plow or disks, which inverts the top portion of the soil and leaves a surface generally free of vegetative matter (Stinner and House 1990). Conventional fields in the Southeast are plowed beginning in the late winter/early spring to prepare the soil for planting. From the first plow of the season, these fields are plowed or disked approximately every 3 weeks until planting. This scenario is obviously unfavorable for nesting birds. Although most species will attempt to renest after nest destruction, they must find another area with suitable vegetative structure similar to that of the field prior to tillage. One of earliest breeding species in the Southeast, the Horned Lark (scientific names appear in Appendix A), a ground nester frequently found nesting in agricultural fields, begins breeding in late February-early March (Cederbaum unpublished data). Even this species would lose most first nest attempts to this early plow. Due to the continuous manipulations of the soil on rotation that is shorter than a typical songbird nesting cycle, all nests initiated during this period would be lost. In addition, some conventional systems maintain weed control through additional cultivation throughout the growing season and therefore destroy later nesting attempts (Castrale 1985). The reduction of vegetation also affects the foraging ability of avian species through a decrease in protective cover and food availability. Studies involving avian use of agriculture fields have shown increased densities along field borders due to the proximity of cover (Best et al. 1990). Aside from the reduction in protection in open fields, complete tillage also alters food availability through both the incorporation of weed seeds to deeper soil depths (Yenish et al. 1992, Hoffman et al. 1998), inaccessible for most songbirds, and destruction of arthropod habitat (Honek 1997). Therefore, the ability for conventional-tilled row crop fields to support sustainable bird populations is questioned due to the extensive nest loss (Rodenhouse and Best 1983, Stallman and Best 1996) and decrease in favorable foraging habitat caused by farming activities.

With changing markets and agricultural specialization, there also has been a drastic change in the coverage and types of crops grown in Georgia. The introduction of synthetic insecticides in the mid 1940's created a method of pest control that was cost effective and efficient. As a result, cultural controls, such as scouting for insects and crop rotation, were abandoned for continuous chemical treatment based on crop phenology (Matthews 1989, Luttrell 1994). Financial lending agencies often required continuous treatment as a term of agreement for borrowers (Bottrell and Adkisson 1977). This emergence of synthetic pesticides altered the use of many crops, but is particularly evident in cotton farming (Bottrell and Adkisson 1977). Since the mid-1980's, the area in cotton production in the Southeast has doubled, totaling 22.6% of the U.S. Production in 2000 (National Agricultural Statistics Service 2001). This is particularly evident in Georgia where most major cash crops have seen a drop in acres farmed in the past 20 years, cotton has increased over 700% (National Agricultural Statistics Service 2001). In 2000, over 600,000 hectares were planted to cotton in Georgia (9.7% of all cotton planted in the U.S.); this totaled 35% of Georgia's cropland. Georgia was second only to Texas in

2000 for total acres planted to cotton (National Agricultural Statistics Service 2001). Due to the increasing acreage devoted to cotton farming in Georgia and the Southeast, it is increasingly important that effects of farming practices on early successional songbirds are determined.

Growing concerns for the overall health of agroecosytems due to the negative impacts of intensive agriculture (e.g., heavy erosion, soil compaction, runoff of pesticides, stream pollution) and economic pressures (rising fuel costs) have resulted in the reemergence of conservation tillage management systems (Christensen and Magleby 1983, Uri 2000). Conservation tillage is a general term referring to any method of reduced tillage that maintains at least 30% of the crop residue on the soil surface (Stinner and House 1990). The percentage of U.S. cropland in some form of conservation tillage has steadily risen from 25.7% in 1989 to 37.2% in 1998 (Conservation Technology Information Center 2001). In conservation tillage fields, farmers do not form seedbeds prior to planting as in conventional tillage fields, and therefore delay any tillage to just prior to or during planting. This comparatively late start for tillage allows many early-nesting birds, such as Horned Larks, nesting in conservational tillage fields to raise at least one successful brood. Soil manipulations for strip-tillage planting, one form of conservation tillage, only turn a portion of the soil. These bands of tilled soil alternate with bands of undisturbed ground. Due to the reduced tillage found with strip-till, the chance for survival during this single-tillage trip is greatly increased over complete tillage of conventional fields. Higher avian densities have been detected in no-till verses conventionally tilled corn and soybean fields (Warburton and Klimstra 1984, Castrale 1985, Basore et al. 1986); while comparisons of reduced-tillage and conventional fields also showed increased density and diversity of avian species in the conservation tillage fields (Flickinger and Pendleton 1994). It is important to note that although reduced tillage agriculture provides a superior habitat as compared to conventional fields, the species diversity of songbirds nesting within row crops is generally low relative to uncultivated areas (Castrale 1985, Best et al. 1990, Freemark et al. 1991, Stallman and Best 1996). While the effects of various agricultural practices on early successional birds have been well studied in the Midwest, the crop types are limited and relatively little is known about the subsequent effects in the southern and western sections of North America (Best et al. 1995, Rodenhouse et al. 1995).

Avian species of concern within Georgia, which could be affected positively by a more ecological approach in agriculture, include Field Sparrow, Eastern Meadowlark, and Grasshopper Sparrow. Data from the North American Breeding Bird Survey show that Field Sparrow and Grasshopper Sparrow populations have declined 40 to 50%, while Eastern Meadowlark numbers have dropped 70% in Georgia during the past 30 years (Sauer et al. 2001). Upon the onset of spring, these seasonally granivorous adults begin to consume arthropods. By the breeding period, insects account for >50% of their diet and closer to 100% for their nestlings. The early nestling diet consists primarily of Lepidoptera larvae (Bent 1965, Carey et al. 1994, Vickery 1996); while several key Lepidopteron account for 60% of the cotton loss to pest insects in the Southeast (Luttrell 1994). The consumption of beneficial insects (i.e., predatory or parasitic) by songbirds is low in agricultural habitats. Instead, songbirds have been shown to more commonly feed on pest insects and weed seeds, thereby aid in maintaining below threshold levels of these pests (Woronecki and Dolbeer 1980, Rodenhouse et al. 1993). A study in the Canadian lowlands examined the effects of birds on pest insects of corn using enclosures and found greatly reduced levels of cutworm (Lepidoptera: *Agrotis* spp.) and weevil (Coleoptera: *Sphenophorus* spp.) damage in open plots situated near field edges. No crop damage caused by avian species was detected (Tremblay et al. 2001). Despite these findings, no difference in corn growth or yield was detected between treatments, which was attributed to the low pest insect populations that were well below damage thresholds. A review of the effect of avian predation on pest levels in agriculture revealed a high level of control in situations of modest to low insect infestations (Kirk 1996). Bollinger and Caslick (1985) found a high positive correlation between adult rootworm (Lepidoptera: *Diabrotica longicornis*) numbers and Red-winged Blackbird detections in areas abounded with rootworms. However, the frequency to which bird species nest or feed in croplands depends on the availability of cover or protection as well as food and, therefore, is affected by field management (Castrale 1985, Rodenhouse and Best 1994, Best et al. 1995, Rodenhouse et al. 1995). Therefore, manipulations that increase structure and diversity within the field and thereby encourage field use by birds could have a positive effect on pest control within crops as well as providing needed habitat.

## EFFECTS OF AGRICULTURE ON INSECT POPULATIONS

The acceptance and increased use of synthetic pesticides also caused changes to agriculture on smaller spatial scales including the community structure of the field. Due to the non-species specific nature of broad-spectrum insecticides, the numbers of beneficial insects as well as target pests were diminished. The overall reduction of the insect community from insecticide use can cause unanticipated outbreaks of secondary pest populations previously controlled by beneficial insects (Luttrell 1994). Beneficial insects are considered to be the most important biological control for pest insects in cotton (Luttrell 1994). In addition, pest insects can develop resistance to some insecticides. As resistance to specific insecticides occurred, newer pesticides were made available to control these pests. Although some growers returned to cultural controls when insects began to show resistance, as new effectual chemicals became available, the reliance shifted back to chemical origin and the cycle was continued (Luttrell 1994). Herbicide use also affects the insect communities within and surrounding agricultural fields through a reduction of cover, food sources, predatory pressure, and over wintering habitat (Freemark and Boutin 1995 and citations within). This response varies according to an insect's life history. Reduced levels of beneficial insects have been attributed to the reduction of field structure due to high herbicide and cultivation to control weeds, leaving no refuge or alternative food sources for the insects (Shelton and Edwards 1983, Phatak 1992, Sotherton and Moreby 1992, Freemark and Boutin 1995, Palmer 1995). Pest species populations have instead been shown to increase with herbicide use (Shelton and Edwards 1983, Laub and Luna 1991, Laub and Luna 1992, Freemark and Boutin 1995), probably due in part to the reduced levels of beneficial insects.

Tillage is considered to be an effective control against some overwintering agricultural pests, particularly boll weevils, *Anthonomus grandis*, and *Heliothis* spp. (Gaylor and Foster 1987). A reduction in tillage raised concerns that damage caused by those pest species may increase in those fields using conservation tillage (Stinner and House 1990 and those within). Studies conducted on the effects of conservation tillage on boll weevil and *Heliothis* spp. damage found no increase on reduced tillage fields

(Gaylor et al. 1984, Gaylor and Foster 1987). In fact, the cultural practices implemented (e.g., delayed planting due to double cropping with a winter cover crop) in reduced tillage actually aided in decreasing boll weevil damage (Gaylor and Foster 1987). In situations where pest populations increased, the cover cropping practices influenced the intensity of the damage (Gaylor et al. 1984). Stinner and House (1990) conducted a review of studies that documented effects of tillage on crop damage by pests. Of the 51 species (in 45 studies) encountered in the literature, they found damage for 28% of the species increased with an increased tillage rate, 29% showed no significant change, whereas 43% had a reduction in damage with an increase in tillage. Predatory and parasitoid populations also have been shown to increase with a reduction in tillage (Warburton and Klimstra 1984, Stinner and House 1990), particularly when coupled with cover crops (Citations in Clark et al. 1997). The affinity of epigeic predators for these field types has been attributed to the favorable microclimate created which provides increased food and shelter and avoids the extreme heat of bare ground found on conventional fields (Honek 1997). Experimentally manipulated levels of predators in cornfields produced damage levels almost 1.5 times higher in conventional fields compared to no-till fields where predators were removed, and four times higher where predators were not removed (Brust et al. 1985). Parasitic insect levels have been reportedly higher within conservation tillage for various crops. It has been suggested that these increases are due in part to the increase in availability of weed species, crop stubble, and cultural practices found in conservation-tilled fields (Citations in Stinner and House 1990). In addition, no-till systems may provide more a desirable habitat for some predatory wasps due to the ground-dwelling nature of their nest.

Many predatory insects can subsist on alternative food sources, such as pollen, nectar, and secondary prey when pest populations are low (Bugg et al. 1990 and citations within). Winter cover crops can supply these necessities prior to the planting of the main crop, therefore allowing levels of beneficial insects to maintain increased levels until the pest insects begin to arrive. Trials conducted in Douglas, Georgia, examined the association between beneficial insect populations in various cover crops relayed with vegetables. Although cover crops varied with regards to weed control, nematodes, disease, and insect level, crimson clover, subterranean clover, and rye were, in general, the best of the crops assessed (Phatak 1993). During trials in South Georgia, the population levels and diversity of beneficial insects in clover have increased over time, so the benefits of clover cover crops may have an additive effect on beneficial insect populations (Yancy 1994). It is important to realize that a high population of beneficial insects does not guarantee the control of pest insects of a desired cash crop. Due to the species or habitat-specific nature of many parasitic insects if the likely pests are not a host of the specific beneficial insects attracted to the cover crop, then the cash crop will not benefit from their presence. Alternatively, the cover crop will not attract required parasitic insects if its host species is not present (French et al. 2001). Additionally, some form of refuge must be left for the beneficial insects (e.g., weedy border vegetation or in field beetle banks) if the cover crop is completely killed off prior to planting of the cash crop. There must be a nearby area that can support the beneficial insects until the crop is established, otherwise the beneficial insects will migrate elsewhere in search of food. In intercropped fields, the timing of germination of the crops will affect the transfer of beneficial insects onto the cash crop. Using mathematical models, Corbett and Plant

(1993) demonstrated that intercropped fields varied as a source or sink for beneficial insects, based on the timing of germination, where those fields in which the interplanted vegetation was established prior to the germination of the crop acted as sources.

Problems associated with heavy usage of pesticides have prompted the emergence and nurtured the continuing growth of Integrated Pest Management (IPM) (Stern et al. 1959, Smith et al. 1976, Luttrell 1994), which refers to a system that uses multiple methods for insect control and generally has a more natural insect composition, rather than strictly relying on the conventional chemical controls (Sotherton 1995, Sundaramurthy and Gahukar 1998). Many techniques are currently being investigated in the U.S. to achieve a more diversified agroecosystem in cotton crops, including the use of transgenic plants, entomopathogens, release of natural enemies, and intercropping (Luttrell 1994). Intercropping refers to an agricultural practice in which two or more row crops are planted in a field at the same time, in alternating, adjacent strips. Intercropping is a way to increase plant diversity, and insect and avian habitat formerly provided in a natural early successional habitat. Relay stripcover cropping, or stripcover cropping, is one type of intercropping that is believed to bring about a more balanced insect community (Bugg et al. 1990, Bugg et al. 1991, Phatak 1992). Relay stripcover cropping in this paper refers to the practice in which rows of winter clover cover crop are left to grow between crop rows throughout the early portion of the cash crop's growing season. This technique allows for the diversification of the structure of a field, as well as the communities within the field. Relay stripcover cropping takes a preexisting feature designed for erosion control and extends its annual duration, incorporating it with the desired cash crop. In doing so, it heightens the beneficial insect levels using attributes already present in the landscape, therefore avoiding unnecessary or costly inputs that many of the other techniques listed above currently require.

## EFFECTS OF ALTERNATIVE AGRICULTURE ON COMMUNITY STRUCTURE

The key, then, to making cotton crops more acceptable for grassland birds is to reduce tillage, diversify the physical structure of the fields while extending its duration, and bring the beneficial and neutral insects back into the system while still controlling pests. Stripcover cropping with conservation tillage appears to be a valid method to achieve this goal. Inclusion of a winter cover crop extends the length of time cover and food is available within an agricultural field, while the incorporation of the cotton crop within the standing cover crop creates a physically diverse habitat of flora and fauna. The actual structure of the cotton plant alone is beneficial to avian species and other small animals. The canopy of the cotton rows provides cover from aerial predators, while the sparse stem vegetation leaves a clear path below in which to forage (J.P. Carroll UGA, personal communication). The interspersion of clover within the cotton would add a component of structural and field diversity lacking in large monocultures. Stallman and Best (1996) found a greater density of Vesper Sparrow nests in intercropping strips (consisting of corn, soybean, oats) than in other agricultural systems. In addition, they found there was a higher occurrence of songbird foraging within these strips, presumably due to an elevated level of sustenance found in the crop residue and clumps of clover, vetch, and weeds. Cotton also attracts a diverse insect community, with beneficial insect diversity reaching as high as 300 species even in areas associated with low precipitation (Gaines 1957, Sundaramurthy and Gahukar 1998). Elevated beneficial insect populations have also been found within various clover cover crops (Bugg et al. 1990, Bugg et al. 1991, Smith et al. 1996, Booij et al. 1997), as well as a reduction of pest species found in cash crops (Theunissen 1994). A reduction in the use of insecticides would allow for a diverse insect community which could control levels of pest insects and provide the increased insect populations needed to furnish the necessary food for adults as well as young birds during the breeding season. In addition to the increase in prey for avian grassland species, there also may be an increase in nesting sites and cover for fledglings within the field, as well as a reduction in nest loss due to the use of conservation tillage (Castrale 1985, Basore et al. 1986). These components of stripcover cropping of cotton could allow the system to provide a good alternative to the declining grassland/early successional habitat in the southeastern U.S.

## STRIPCOVER CROPPING

Preliminary results of trial plots of clover stripcover cropping in cotton during 1998 demonstrated that beneficial insect population levels were high enough to eliminate the need for insecticide applications (A. Walker, personal communication). The results of these trials paralleled those found in a similar study conducted by Phatak et al. (1999) in Douglas, Georgia, in which no pesticides were applied throughout a 5-year field study. In addition, these stripcover fields produced higher cotton yields than the state average during all 5 years. These findings suggest that stripcover cropping of cotton is an environmentally sensitive way to grow cotton in Georgia. Preparation for stripcover cropping begins in the fall when a cover crop of clover is planted. This winter cover crop allows populations of beneficial insects to become established before the cotton crop is planted in early May. When preparing the land for cotton, instead of harvesting, burning, or plowing the cover crop, a 0.5 m strip of clover is hood-sprayed with Roundup® (active ingredient: Glyphosate) and cotton is planted with reduced tillage, in this cleared strip. This leaves about 0.5 m of clover between the rows of cotton, which later, after the cotton reaches the four-leaf stage, is narrowed down to 20-25 cm, if necessary. This last decrease of clover acts to reduce the competition for nutrients and water between the existing clover and the growing cotton (Phatak 1992). As the growing season progresses, the cover crop dies back naturally or is chemically suppressed, depending on its hardiness. The structure and vegetative matter of the residual clover will sustain neutral and beneficial insects for an extended period (J.P. Carroll UGA, personal communication), while some of these insects move to the growing cotton crop. This movement maintains a high population of beneficial insects in the field throughout the summer and consequentially can depress the pest population for the same period (Bugg et al. 1990, Bugg et al. 1991, Phatak 1992). While achieving a better balance in the field and allowing natural processes to control the system, farmers can realize a reduction in cost to maintain beneficial levels of nutrients and pest control. The potential for increased yields demonstrated previously in stripcover trial fields, coupled with reduced front-end costs, would produce a much higher profit for the farmer (Phatak et al. 1999).

# STUDY AREA AND METHODS

## Study Area

Study sites were located on the Upper Coastal Plain of Georgia within a 50-km radius in Jefferson, Burke, Washington, Jenkins, and Johnson Counties (Figure 1). Thirty percent of cotton farmed in these counties used conservation tillage during 1998, double the state's average (Conservation Technology Information Center 2001). This area is characterized by well-drained, gently sloping, sandy loam to sandy soils. In 1982, sixty two % of Georgia's prime farmland was found in the Southern Coastal Plain (Hodler and Schretter 1986). Farmland accounts for 40 to 50% of the land in the area with the average farm size ranging from 135 to 245 ha (Boatright and Bachtel 1999). Average monthly temperature ranged from 4º C (December 2000) to 29º C (August 1999) during 1999 and 2000. Total precipitation during this period was 196 cm (105 cm in 1999 and 91 cm in 2000). Rainfall during 2000, the third consecutive drought year, reached 25 cm below normal.

## Experimental Design

During 1999, we monitored seven fields in relay stripcover with conservation tillage (Clover), seven in conservation tillage and traditional rowcropping (Conservation), and the remaining seven used traditional methods for both tillage and pesticide treatments (Conventional) (21 fields total in 1999, the number of replicates was reduced to 5 in 2000 for a total of 15 fields) (Table 1). All fields were planted annually in cotton with no crop

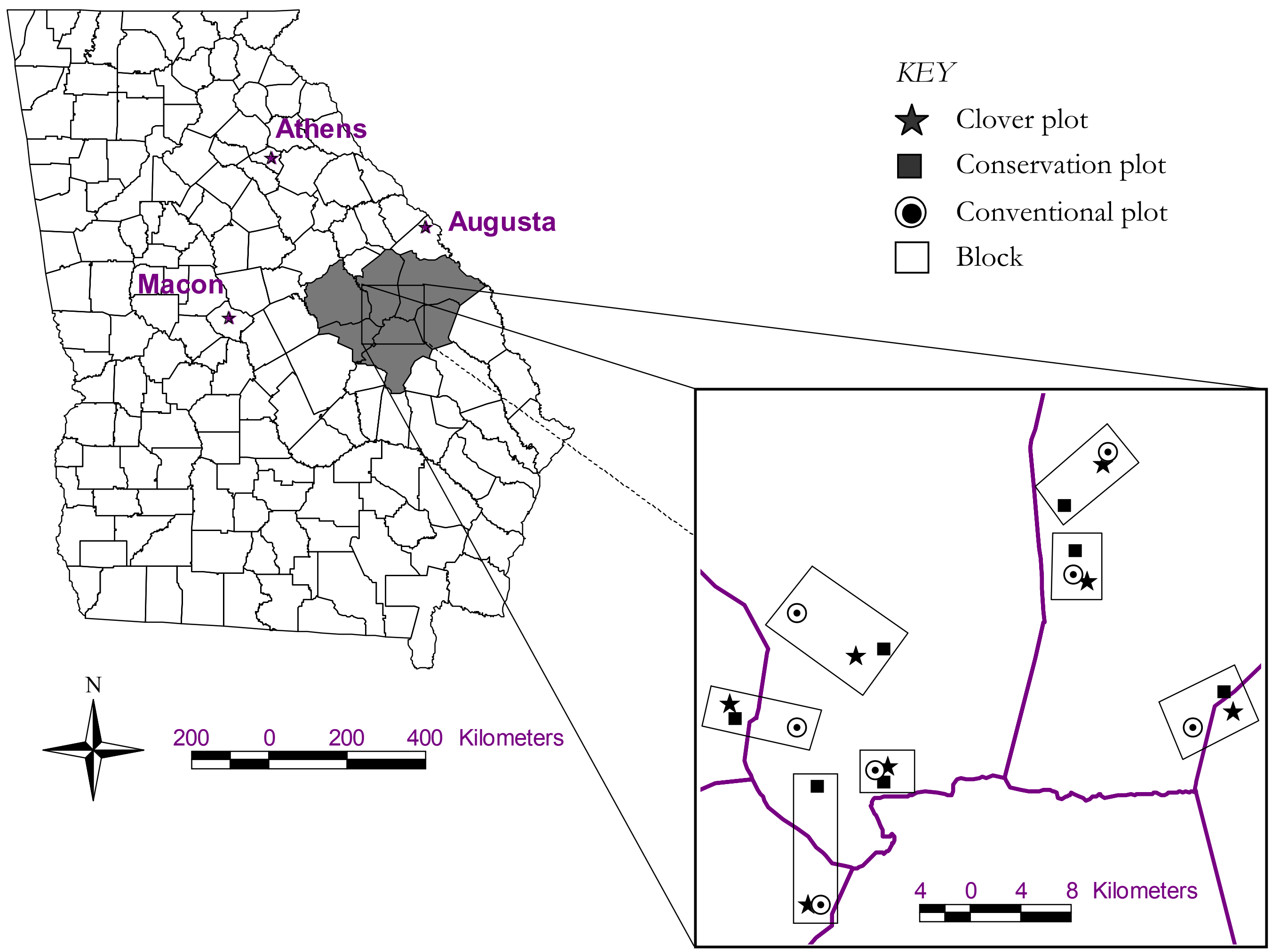


Figure 1. Plot layout of cotton fields for avian population study in central Georgia during 1999. Although some plots were dropped from the study and the number of blocks dropped to five due to drought conditions during 2000, the study design remained similar.

Table 1. Plot characteristics, including timing and treatment applications, for avian density study in cotton fields in central Georgia, during 1999 and 2000.

| Treatment | Management practices | Plot | Year used | Hectares | County |
|---|---|---|---|---|---|
| Conventional | ~complete tillage<br>~began tillage in early March<br>~herbicides used<br>~insecticides used | 1C | 99/00 | 10 | Burke |
| | | 2C | 99 | 5 | Burke |
| | | 3C | 99/00 | 7 | Burke |
| | | 4C | 99 | 7 | Johnson |
| | | Φ 4C00 | 00 | 14 | Jefferson |
| | | 5C | 99 | 12 | Jefferson |
| | | Φ 5C00 | 00 | 19 | Jefferson |
| | | 6C | 99 | 18 | Jefferson |
| | | 6C00 | 00 | 10 | Jefferson |
| | | 7C | 99 | 8 | Jefferson |
| Conservation | ~reduced tillage; strip-till<br>~began tillage in early May<br>~used herbicides<br>~used insecticides | 1N | 99/00 | 18 | Burke |
| | | 2N | 99 | 3 | Burke |
| | | 3N | 99/00 | 17 | Burke |
| | | 3N00 | 00 | 14 | Burke |
| | | ξ 4N | 99/00 | 8 | Jefferson |
| | | 5N | 99 | 15 | Jefferson |
| | | 5N00 | 00 | 28 | Jefferson |
| | | ψ 6C/N | 00 | 14 | Jefferson |
| | | 6N | 99 | 9 | Jefferson |
| | | 6N00 | 00 | 20 | Jefferson |
| | | 7N | 99 | 40 | Washington |
| Clover | ~reduced tillage; strip-till<br>~began tillage in May<br>~herbicides used<br>~no insecticides | ξ 1L | 99/00 | 35 | Burke |
| | | 2L | 99 | 4 | Burke |
| | | 3L | 99/00 | 6 | Jenkins |
| | | 4L | 99/00 | 7 | Johnson |
| | | ξ 5L | 99/00 | 5 | Jefferson |
| | | Φ 6L | 99/00 | 10 | Jefferson |
| | | 7L | 99 | 12 | Washington |

ξ Those plots that were lost due to drought (during 2000)

Φ Those plots that switched to soybeans after cotton crop was lost (during 2000)

ψ Plot that switched from Conventional to Conservation mid-season rotation on most fields. It is common, in this part of Georgia, to plant cotton in the same field for a period of 10-15 years, even though cotton yield on most fields begins to drop after the 4-5th year (A. Walker, personal communication). Weed control for Clover and Conservation fields was strictly through application of Roundup® without cultivation and all cotton plants in all three treatments were a Roundup Ready® variety. The length of time a field has been managed under a particular treatment ranged from 1 to 4 years for Clover, 1-10 years for Conservation, and >10 years for Conventional. Study sites were arranged in a randomized complete block design, with each Clover field situated in close proximity to both a Conventional and Conservation field, with distances ranging from less than 0.5 to 10.5 km, with most plots within 4.5 km. Field sizes ranged from 3 to 94 ha.

SONGBIRD USE OF AGRICULTURAL FIELDS

*FIELD METHODS:* Avian use of agricultural fields was monitored using distance transects following Burnham et al. (1980). Data were collected from 5 April to 27 July, during 1999 and 24 February through 23 July, during 2000. We conducted surveys between dawn and 1000 hours throughout spring migration and the breeding season during 1999 and 2000, and additionally during the late winter in 2000. The surveys were performed during 10 and 7 day survey periods, in 1999 and 2000, respectively. This allowed an increased sample size during 2000 although the same time periods were used for each season in both years (Table 2). All fields were visited one time during each survey period with each field having at least one transect randomly placed through the central portion of the field running parallel with the crop rows. To reduce potential observer

Table 2. Survey number and dates as they relate to avian seasons in central Georgia, during 1999 and 2000.

| | Survey | Date |
|---|---|---|
| **1999** | | |
| Migration | 1-2 | 5 April to 29 April |
| Breeding | 3-11 | 30 April to 27 July |
| **2000** | | |
| Winter | 1-3 | 24 February to 19 March |
| Migration | 4-8 | 21 March to 22 April |
| Breeding | 9-21 | 24 April to 23 July |

bias, observers were rotated among fields. Transects were assigned randomly in the field each visit by selecting a field corner at random with a compass. Then, from the random corner, the observer walked 50 m along the border plus a random number between 0-99. this was the starting point for the transect. All transects ran parallel with the row as long as the rows were straight. For each detection of an individual or group on a given transect the species, number of individuals in a group, perpendicular distance, and vocal activity (i.e., singing or calling) were recorded. Birds were only recorded if on the ground or actively using the area (e.g., singing from a perch, aerially foraging, hunting for local prey). Only birds detected while observers were on the center line were recorded. All distances were measured to the nearest ½ m by either a Rolatape® measuring wheel or by counting crop rows, which were spaced approximately 1 m apart for cotton. When a bird flushed, care was taken to determine where birds flew to ensure individuals were not recorded twice either on the same transect or on a subsequent one (see below). If a group of birds was detected, the distance to the center of the cluster was recorded. If, upon completion of a transect, the field was large enough to fit another transect, the next transect was chosen by continuing along the border 50 m plus a random number as before. If this location was not far enough away from the previous transect so as not to recount birds, then the observer continued along the border, in increments of 25 m, until detections made on the transect would be independent. Transects were conducted so that no two surveys (for different survey periods) on a given plot were conducted within 3 days of each other.

*Analysis by Behavior Guild:* Survey data were analyzed by season in a given year. We determined seasons based on the timing of migration and the breeding season

(Table 2). For each season, birds were grouped by species and three general behavior guilds: sparrow, scrub, and ground. The sparrow guild (SPARROW) were species that tended to be small, neutral colored, secretive, run along the ground and consisted of mostly sparrows. Those species in the scrub guild (SCRUB) were highly vocal, of a larger body size, and generally perched on tops of vegetation and came from a variety of families. The last guild (GROUND) consisted of those species that were of a larger body size and varied in the intensity of vocalization, but were more difficult to see due to their ground-dwelling nature (Appendix A). Not all species fell into one of the three behavioral guilds. These species were included, along with those from the previous guilds, into a fourth group, ALL.

Program DISTANCE 3.5 (Thomas et al. 1998) was used to determine density per treatment of all behavioral guilds in which detections of clusters were greater than 40 in a given season (Burnham et al. 1980) (Table 3). Truncation of extreme horizontal distances was required for all data sets and ranged from 2.5-20% (mean 5.4%). Multiple models were tested for each data set with a variety of groupings to achieve the best possible fit. The best model was chosen based primarily on the Akaike Information Criterion (AIC), within groupings, while also considering Goodness-of-Fit, especially near the zero distance (Buckland et al. 1993).

During the 2 year period in which this study took place, Georgia was in a period of intense drought. The 2000 growing season was extremely difficult for many farmers and many abandoned their fields or plowed under the cotton crop to plant soybeans (7 out of 15 fields were lost; 3 were abandoned, 3 switched to soybean, and one switched treatments; Table 1). Therefore the analysis for the 2000 Breeding period was truncated

Table 3. Number of detections of avian clusters grouped by behavioral guild for each season within three treatments of cotton fields in central Georgia, 1999-2000. No transects were conducted during Winter 1999.

| | Treatments | | | | | |
|---|---|---|---|---|---|---|
| | *Conventional* | | *Clover* | | *Conservation* | |
| | **1999** | **2000** | **1999** | **2000** | **1999** | **2000** |
| **Winter** | | | | | | |
| sparrows | - | 9 | - | 39* | - | 93* |
| ground | - | 2 | - | 14 | - | 13 |
| scrub | - | 0 | - | 3 | - | 0 |
| all | - | 17 | - | 65* | - | 113* |
| **Migration** | | | | | | |
| sparrows | 0 | 43* | 29 | 179* | 17 | 178* |
| ground | 11 | 14 | 15 | 22 | 8 | 27 |
| scrub | 4 | 0 | 4 | 61* | 15 | 37 |
| all | 16 | 67* | 49* | 287* | 48* | 268* |
| **Breeding** | | | | | | |
| sparrows | 0 | 0 | 21 | 47* | 7 | 29 |
| ground | 31 | 14 | 150* | 79* | 69* | 63* |
| scrub | 25 | 19 | 114* | 349* | 113* | 136* |
| all | 76* | 64* | 326* | 527* | 231* | 289* |

* Groups in which density could be estimated with program DISTANCE

after the 17th survey (24 June) (the period when drought related changes in management began to occur).

*ANALYSIS BY SPECIES:* Due to the low detection numbers for individual species during a given season, we conducted these analyses graphically using the mean number of detections and 95% confidence intervals. Confidence intervals which did not overlap were judged to be significantly different ($P = 0.05$)(Scheaffer et al. 1996). All species with >20 detections for a season on a plot were included in the analysis. For each survey, all transects conducted on a given field were summed by length and the total number of birds for each species. Each transect was then adjusted for the number of birds of a given species per 800 m (average total transect length for a field), then averaged for a plot within each season. This number was then averaged across plots within a treatment. Ninety-five percent confidence intervals were developed around the mean of each treatment. We again truncated the analysis for Breeding 2000 after the 17th survey (24 June) due to the drought. Species richness and Shannon-Wiener diversity indices (Appendix B) were determined using 1999 and 2000 data.

## ARTHROPOD SAMPLING

*FIELD METHODS:* Pitfall traps were used to sample ground-dwelling arthropods. We placed one circle of eight traps (diameter of 40 meters) on each of the fields (21 fields in 1999 and 15 fields in 2000). The center point of the circle was assigned randomly in the field each year by selecting a field corner at random with a compass then walking 50 m from that corner, along the border, plus a random number between 0-99. The center point was then placed 50 m into the field perpendicular to the randomly selected spot on the border. The density and species of arthropods are influenced by the proximity and type of border (van Emden 1965, Mayse and Price 1978), so this ensured that all sampling points would be at least 30 m from an edge (maximum distance possible on the smallest field) and would reduce capture of edge species. Once the center point was determined, a direction was selected randomly using a compass and the first trap was placed 20 m from the center point in this direction. The remaining seven traps were placed every 45° from the random direction (approximately 15.7 m apart). Traps consisted of a Solo® plastic beverage cup (470 ml with a 9 cm opening) placed flush with the ground. We attempted to have all cups in place for 2 weeks prior to sampling to reduce sampling bias for species associated with disturbance (e.g., Formicidae, some members of Carabidae; Greenslade 1973, Digweed et al. 1995). These precautions were not always possible given the transient nature of agricultural systems due to the soil preparation for planting. During a sampling period a small plastic cup (120 ml with a 6 cm opening) filled with 70% ethyl alcohol was placed within each base cup and a plastic funnel cup (Solo Cozy Cup Refill®) with the bottom removed (210 ml, 9 cm top and 3.5 cm bottom diameter) was placed on top and flush with the base cup. Traps were left open for a 24-hr period on a bi-weekly basis from early-May through late-July in 1999, and mid-April through mid-July in 2000.

Due to time limitations, we analyzed a subset of the samples from 1999 and no samples from 2000. A subsample of four (out of eight) randomly selected samples was analyzed from one sampling period per month in 1999 (possible total of 252 samples). Some samples were lost during storage due to mold (ten samples) and one entire sampling unit (four samples) was lost due to agricultural activities during the 24-hour sampling period. There was a total of 238 samples included in analyses. Insects were identified to Order and to Family when possible. Length and width measurements (to the nearest 0.1 mm) were taken on each arthropod using Spi® calipers. Insect biomass was estimated using length and width regression models (Palmer 1995) (Appendix C).

*ANALYSIS OF ARTHROPOD DATA:* The biomass and total number of arthropods for each plot per month were determined by averaging all usable samples per plot during each sampling period. These means were then used in a Complete Block Analysis of Variance (ANOVA) to test for treatment effects for each month (SAS Institute 1990). The blocking effect was not statistically significant ($P \leq 0.05$) in any of the analyses, therefore all analyses were conducted using a one-way ANOVA with degrees of freedom and sums of squares absorbed into the error quantities. Repeated Measures ANOVA could not be employed for this, or any of the arthropod analyses due to the missing values caused by the destruction of all samples on Plot 7N during June 1999.

Arthropod families were grouped into two categories (Pest or Beneficial/Neutral) based on the documented effect the members of a family had on cotton crops (Appendix C)(Little and Martin 1942, Toscano et al. 1979, DeBach and Rosen 1990, Hill and Hill 1994). Those families with major cotton crop pests or those with multiple minor pests were considered Pest Families (PEST). Those families with parasitic or predacious insects, those that provided pollination of the crop, or those that have not been shown to have an effect on the cotton crop were considered Beneficial/Neutral Families (BEN). Biomass and total numbers for each plot per month were determined for both PEST and BEN categories. Samples were averaged within each plot for each category then used in a Complete Block MANOVA using PEST and BEN as response variables. For those analyses where the MANOVA for the block effect was not significant ($P \leq 0.05$) the block was removed and analyzed with a MANOVA as described above for ANOVA.

VEGETATION SAMPLING

*FIELD METHODS:* Vegetation parameters were measured by the observer while conducting each avian survey. Average measurements were estimated for each plot at the field level for percentage cover for all green vegetation (GREEN), bare ground (BARE), standing dead biomass (DEAD), and downed dead biomass (LITTER). A fifth percentage vegetation, COVER, was created by summing percentages GREEN and DEAD (100% maximum), to determine the percentage of total standing vegetation covering the plot. Average heights for plot vegetation were estimated for cotton, cover crop (clover or winter wheat), and weeds. Farming manipulations that altered the field (plow, plant, and herbicide) and dates were recorded for all known operations.

*ANALYSIS OF VEGETATION DATA:* Correlations were determined between percentage vegetation and number of birds for each percentage vegetation/behavioral guild/season combination. Spearman's rank correlation was used since the vegetation data were measured in percentages. Avian data were standardized for field size using a similar procedure described in "Songbird Use of Agricultural Fields - Analysis by Species." All transects conducted on a given plot were summed by length and the total number of birds for each behavioral guild, for each survey. This extended transect was then adjusted for the number of birds of a given guild per 800 m (average total transect length for a field).

The variations in percentage vegetation types due to treatment were examined using a Complete Block ANOVA for each season. Percentage data for each survey were normalized using an Arcsine transformation.  A single value was created for each vegetation type by averaging the transformed values for each plot within each season. Due to the extreme drought and field loss in 2000 the original experimental design was altered during the Breeding season, so that the final analysis for this period, when these change took place, only included those fields still in cotton production.  The blocking effect was not significant ($P \leq 0.05$) in any of the analyses except Winter 2000 for GREEN, therefore all other analyses were conducted using a one-way ANOVA without blocking.  Final vegetation values for each treatment were transformed back into percentages.

# RESULTS

## <u>Songbird Use of Agricultural Fields</u>

Clover cover cropping had a positive effect on overall avian populations. During 1999, all behavioral groups (with enough detections to determine density) had the highest number of detections in the Clover treatment for all seasons except during Breeding when Conservation plots had higher densities in the SCRUB guild (Table 4). The same elevated trends for Clover were exhibited during all seasons in 2000 except SPARROW densities were higher on the Conservation treatment during the Winter. Conventional plots lacked enough detections to calculate densities for all periods for both SCRUB and GROUND guilds during both years. Detections of individual species varied based on species habitat requirements, but the overall tendency was increased numbers on Clover fields. Yearly variation for both guilds and species is attributed to species composition and decreased sample size during 1999.

*Behavioral Group Densities:* During Winter 2000, densities for SPARROWS, although higher for Conservation plots, showed no difference from Clover plots (Figure 2). Similarly, no differences were detected between Clover and Conservation tillage plots for ALL (Figure 3). Conventional plots did not have enough detections to compute density for either guild. No treatment had enough detections in the SCRUB or GROUND guilds to determine densities and, therefore, could not be compared. The only group with enough detections to be analyzed with DISTANCE during Migration 1999 was ALL (Table 3). Although the Clover treatment had a higher density, there was no significant

Table 4. Spearman's rank correlation values for three avian behavioral guilds and various vegetation parameters within cotton fields in central Georgia during 1999 and 2000.

| | | SPARROW[1] | | SCRUB | | GROUND | |
|---|---|---|---|---|---|---|---|
| **1999** | | $r_s$ | p value | $r_s$ | p value | $r_s$ | p value |
| Migration | GREEN | 0.908 | <0.0001 | 0.145 | 0.784 | -0.543 | 0.266 |
| | BARE | -0.841 | 0.0006 | -0.667 | 0.148 | 0.086 | 0.872 |
| | DEAD | 0.364 | 0.025 | 0.706 | 0.117 | -0.116 | 0.827 |
| | LITTER | 0.274 | 0.388 | 0.462 | 0.356 | -0.820 | 0.046 |
| | COVER | 0.792 | 0.002 | 0.580 | 0.228 | 0.086 | 0.872 |
| Breeding[2] (reduced) | GREEN | Do Not Breed in Area | | 0.543 | 0.266 | -0.600 | 0.208 |
| | BARE | | | -0.543 | 0.266 | 0.829 | 0.042 |
| | DEAD | | | 0.657 | 0.156 | -0.943 | 0.005 |
| | LITTER | | | 0.771 | 0.072 | -0.829 | 0.042 |
| | COVER | | | 0.543 | 0.266 | -0.829 | 0.042 |
| Breeding | GREEN | | | 0.215 | 0.282 | -0.184 | 0.358 |
| | BARE | | | -0.594 | 0.001 | 0.036 | 0.860 |
| | DEAD | | | 0.624 | 0.0005 | 0.029 | 0.884 |
| | LITTER | | | 0.661 | 0.0002 | -0.002 | 0.992 |
| | COVER | | | 0.467 | 0.014 | -0.176 | 0.381 |
| **2000** | | | | | | | |
| Winter | GREEN | 0.594 | 0.092 | Do Not Winter in Area | | 0.577 | 0.104 |
| | BARE | -0.733 | 0.025 | | | -0.450 | 0.224 |
| | DEAD | 0.159 | 0.683 | | | 0.176 | 0.651 |
| | LITTER | 0.283 | 0.460 | | | -0.017 | 0.966 |
| | COVER | 0.567 | 0.112 | | | 0.567 | 0.112 |
| | HEIGHT | 0.795 | 0.010 | | | 0.569 | 0.110 |
| Migration | GREEN | 0.833 | <0.0001 | 0.831 | 0.0001 | 0.188 | 0.503 |
| | BARE | -0.619 | 0.001 | -0.768 | 0.0008 | -0.286 | 0.920 |
| | DEAD | 0.143 | 0.504 | 0.678 | 0.005 | 0.034 | 0.904 |
| | LITTER | -0.290 | 0.169 | 0.042 | 0.881 | -0.590 | 0.021 |
| | COVER | 0.714 | <0.0001 | 0.869 | <0.0001 | 0.193 | 0.491 |
| | HEIGHT | 0.171 | 0.426 | 0.7755 | 0.0007 | -0.125 | 0.965 |

Table 4. Continued.

| | | SPARROW[1] | | SCRUB | | GROUND | |
|---|---|---|---|---|---|---|---|
| | | $r_s$ | p value | $r_s$ | p value | $r_s$ | p value |
| Breeding (reduced) | GREEN | Do Not Breed in Area | | 0.883 | 0.002 | 0.683 | 0.042 |
| | BARE | | | -0.800 | 0.010 | -0.600 | 0.088 |
| | DEAD | | | 0.250 | 0.517 | 0.000 | 1.000 |
| | LITTER | | | 0.483 | 0.188 | 0.283 | 0.460 |
| | COVER | | | 0.783 | 0.013 | 0.633 | 0.067 |
| | HEIGHT | | | 0.593 | 0.092 | 0.339 | 0.372 |
| Breeding | GREEN | | | 0.526 | 0.0006 | 0.388 | 0.015 |
| | BARE | | | -0.835 | <0.0001 | -0.563 | 0.0002 |
| | DEAD | | | 0.438 | 0.005 | 0.231 | 0.158 |
| | LITTER | | | 0.507 | 0.001 | 0.441 | 0.005 |
| | COVER | | | 0.728 | <0.0001 | 0.370 | 0.021 |
| | HEIGHT | | | 0.690 | <0.0001 | 0.346 | 0.031 |

[1] Because most Sparrow species sampled do not breed in this area, Sparrow migration periods were extended to include extra transects from Breeding periods when they were still in the area (2 in 1999 and 3 in 2000).

[2] Reduced breeding periods included transects 3-4 during 1999 and 9-11 during 2000.

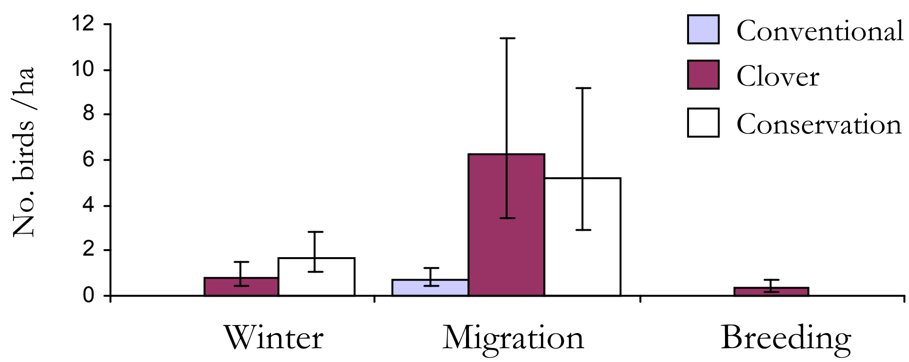


Figure 2. SPARROW guild densities (± 95% CI) from central Georgia in 2000. During 1999, no seasons had enough detections to determine densities.

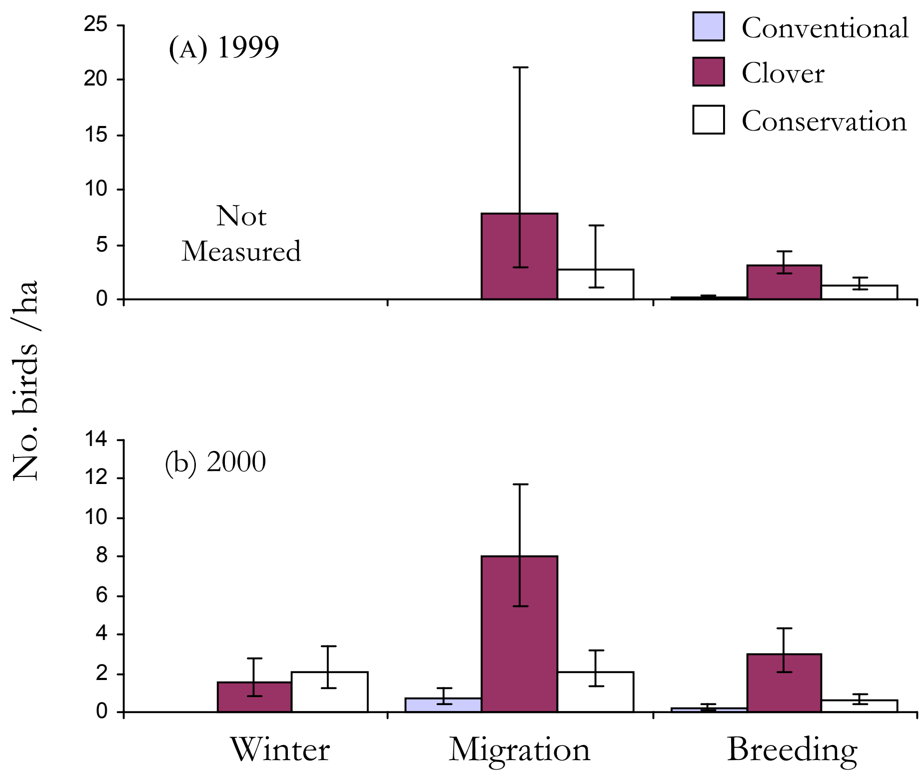


Figure 3. ALL species densities (± 95% CI) from central Georgia during (a) 1999 and (b) 2000. Fields were not surveyed during Winter 1999.

difference between Clover and Conservation tillage (Figure 3). Detections for Conventional plots were not high enough to determine densities. During 2000, densities for ALL species were significantly higher for Clover treatments than both Conservation and Conventional tillage plots, which did not differ from each other. SPARROW densities showed no difference between Clover and Conservation tillage treatments, whereas both were significantly larger than the density found on Conventional fields (Figure 2). Clover was the only treatment with enough detections for SCRUB to determine density (Figure 4).

During the Breeding seasons there was no difference between Clover and Conservation plots for the SCRUB behavioral group in 1999, while Clover far exceeded Conservation densities in 2000 (Figure 4). During this period the Conventional plots lacked enough detections to determine density (Table 3). For the GROUND group, Clover plots had a significantly higher density (over 4 times) than Conservation tillage plots during 1999 and about 2.5 times higher in 2000, but was not significant (Figure 5). Conventional plots did not have enough detections for density either year to be calculated. Due to low detection numbers in Clover (1999) and Conservation (1999 and 2000) and no detection in Conventional treatments, SPARROW density could only be determined for the Clover treatment during 2000 (Figure 2). ALL species, again showed a higher density for Clover plots, but only significantly different from Conservation tillage plots during 2000 (Figure 3). Both treatments, however, had significantly higher densities than the Conventional tilled plots during both years.

*SPECIES DETECTIONS:* Detections of Eastern Meadowlarks during Winter 2000 were significantly higher on Clover plots than both Conservation and Conventional

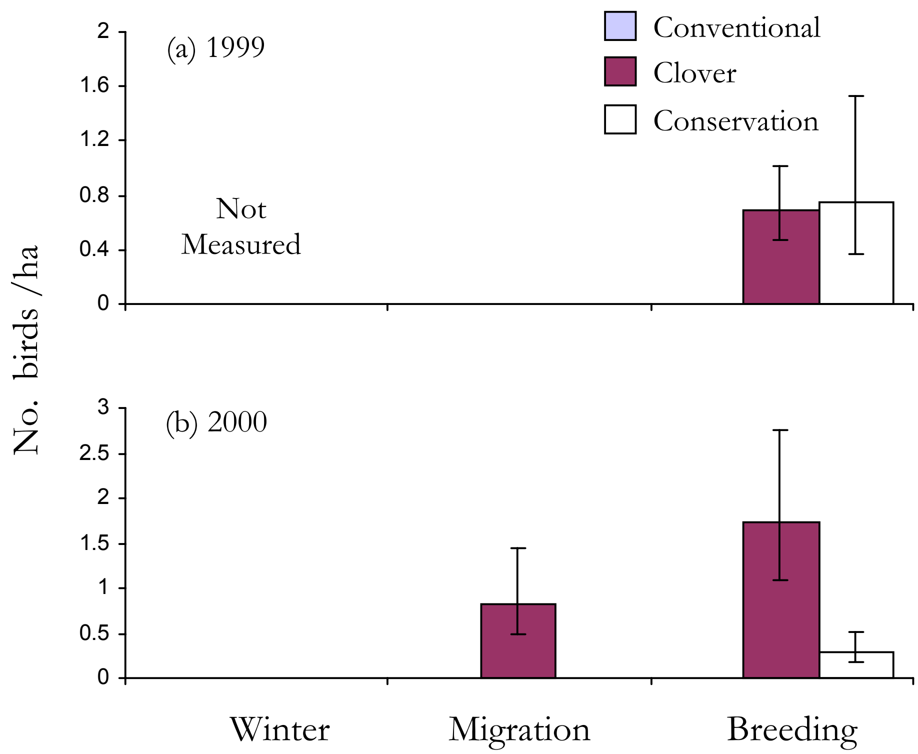


Figure 4. SCRUB guild densities (± 95% CI) from central Georgia during (a) 1999 and (b) 2000. Fields were not surveyed during Winter 1999.

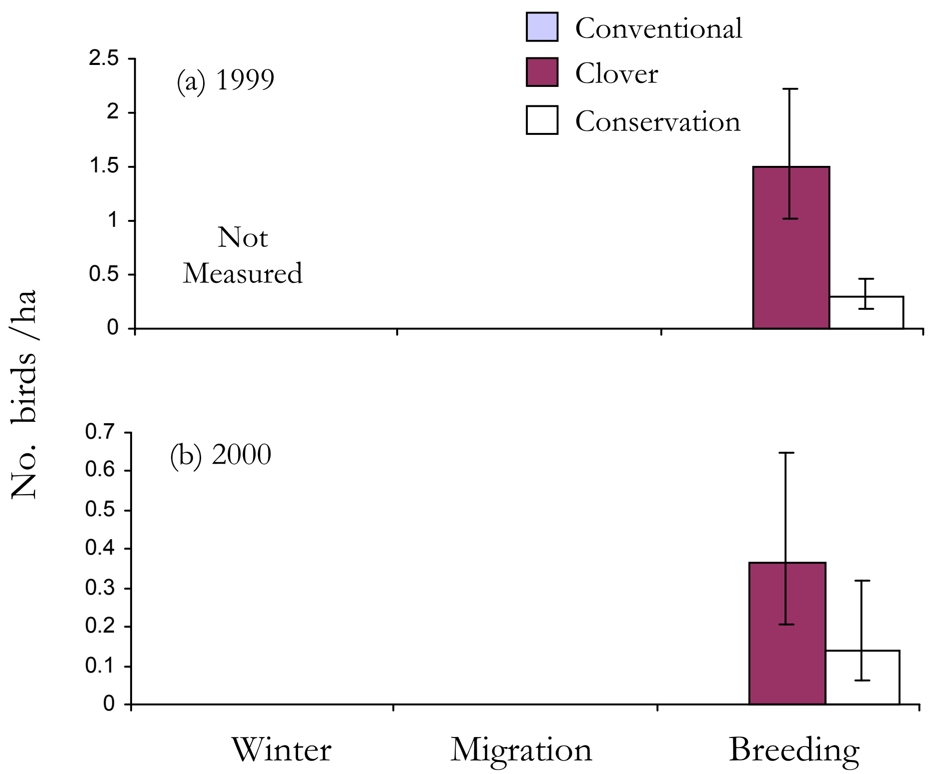


Figure 5. GROUND guild densities (± 95% CI) from central Georgia during (a) 1999 and (b) 2000. Fields were not surveyed during Winter 1999.

fields, with no detections on Conventional fields (Figure 6). Savannah Sparrow detections were greater on Clover and Conservation than Conventional fields, although only Clover was significant. No significant differences were detected between plots for Song Sparrows, although detections were higher for Conservation plots. During Migration, detections for Savannah Sparrows did not differ significantly between Clover and Conservation treatments for either year, although detections are greater in Clover (Figure 7). No Savannah Sparrows were detected in Conventional fields during 1999 and had significantly fewer detections than Clover in 2000 (Figure 8). Abundance of Red-winged Blackbirds varied between years with no significant difference between Clover and Conservation treatments in either year. Clover had significantly higher detections then Conventional in 2000, with no Red-winged Blackbirds detected in Conventional fields. Mourning Dove detections during 1999 were slightly higher in Conventional plots, followed by Conservation, and least in Clover plots, although none was significant. No significant differences between the plots were observed for Song Sparrow or Eastern Meadowlark in 2000, although the detections followed the same general high to low trend Clover/Conservation/Conventional, respectively.

During Breeding 2000, all species detections were highest on Clover plots though only some were significant. Red-winged Blackbirds were detected at higher rates in Clover plots during both years (although only significant during 2000), followed by Conservation, and finally Conventional plots (Figures 9 and 10). Detection of Eastern Kingbirds varied by year, but was greater on Conservation and Clover plots than Conventional fields, although only Clover plots were significantly higher (1999). While 2000 detections did not differ between treatments, means were highest on Clover.

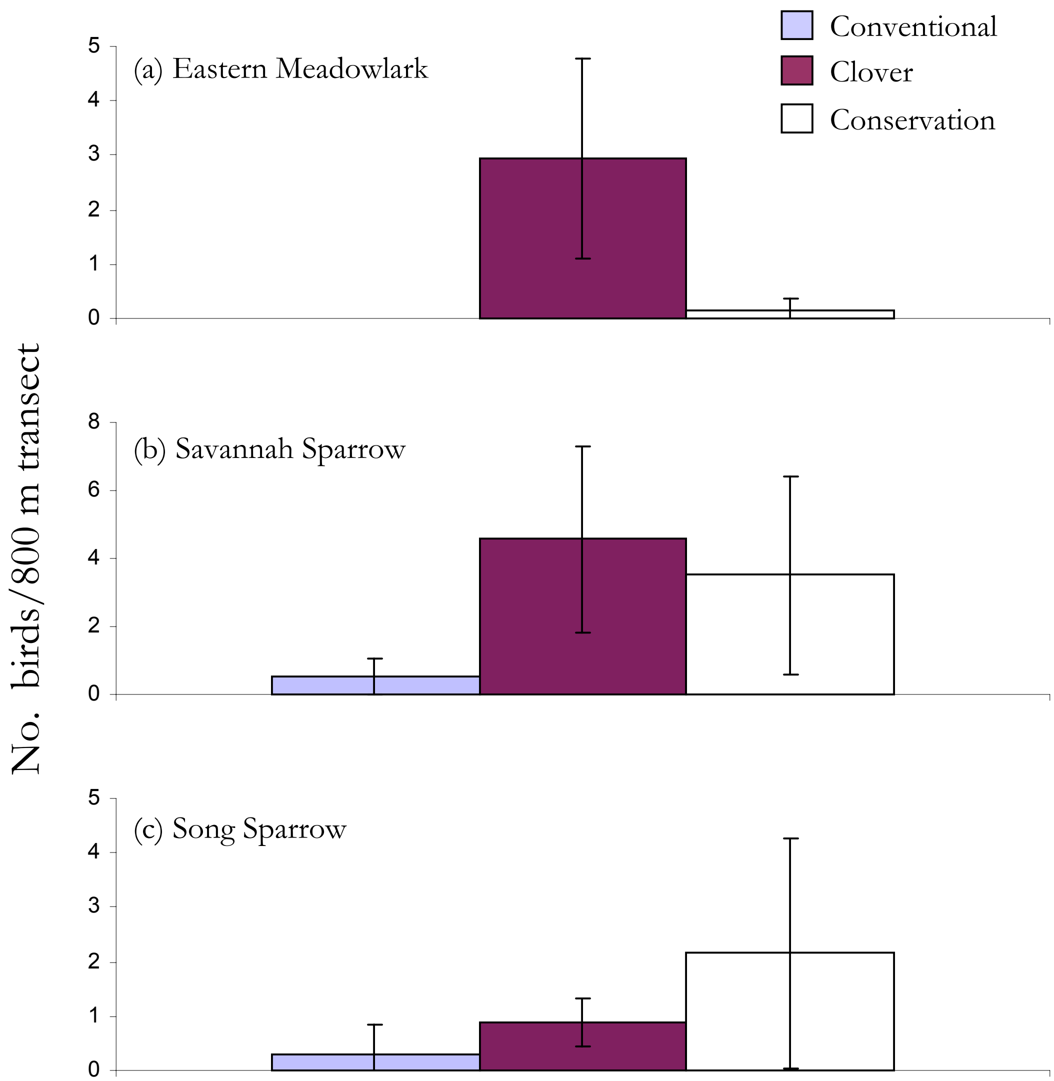


Figure 6. Mean number of detections (± 95% CI) of (a) Eastern Meadowlark, (b) Savannah Sparrow and, (c) Song Sparrow on Conventional, Clover, and Conservation cotton fields during Winter of 2000.

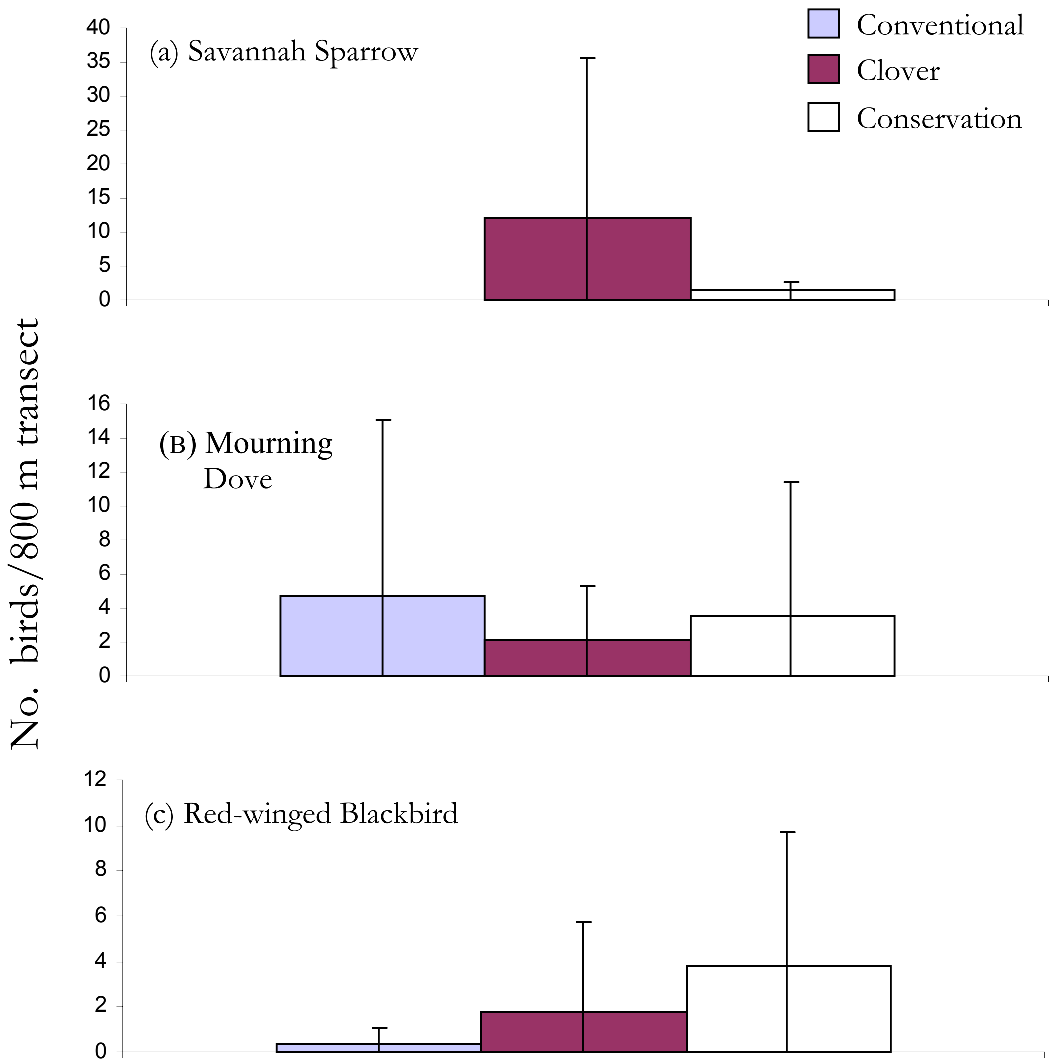


Figure 7. Mean number of detections (± 95% CI) of (a) Savannah Sparrow, (b) Mourning Dove and, (c) Red-winged Blackbird on Conventional, Clover, and Conservation cotton fields during Migration of 1999.

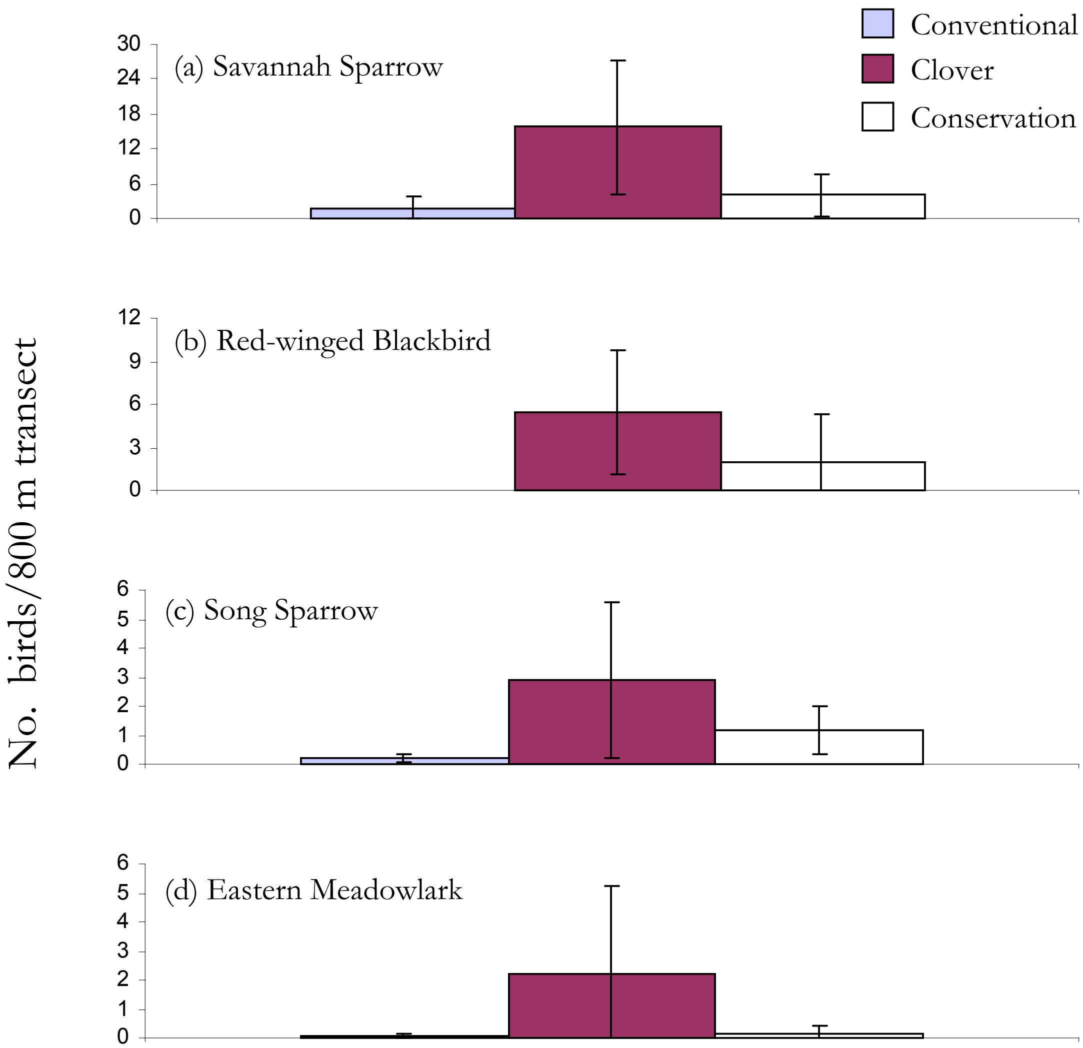


Figure 8. Mean number of detections (± 95% CI) of (a) Savannah Sparrow, (b) Red-winged Blackbird, (c) Song Sparrow and, (d) Eastern Meadowlark on Conventional, Clover, and Conservation cotton fields during Migration of 2000.

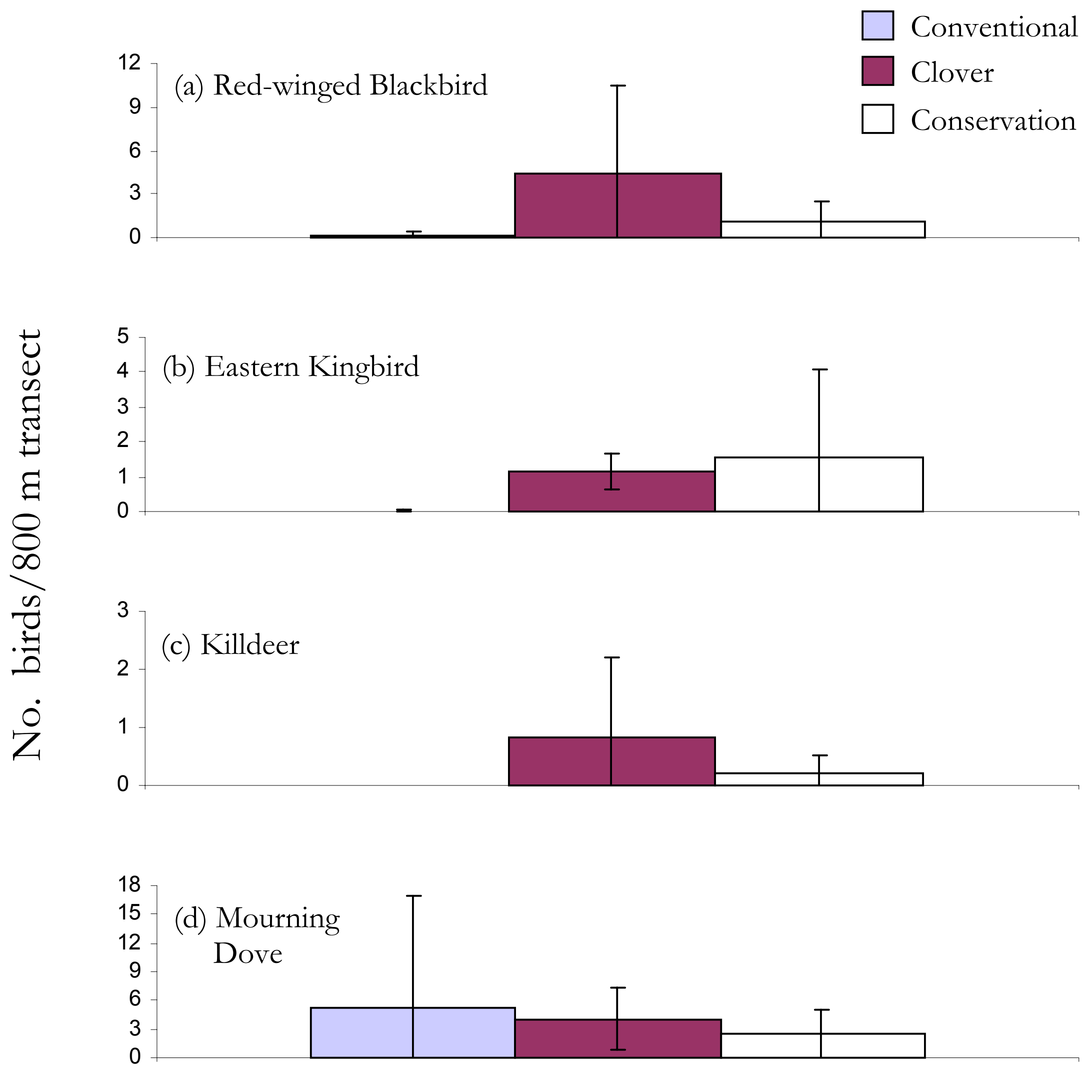


Figure 9. Mean number of detections (± 95% CI) of (a) Red-winged Blackbird, (b) Eastern Kingbird, (c) Killdeer and, (d) Mourning Dove on Conventional, Clover, and Conservation cotton fields during Breeding of 1999.

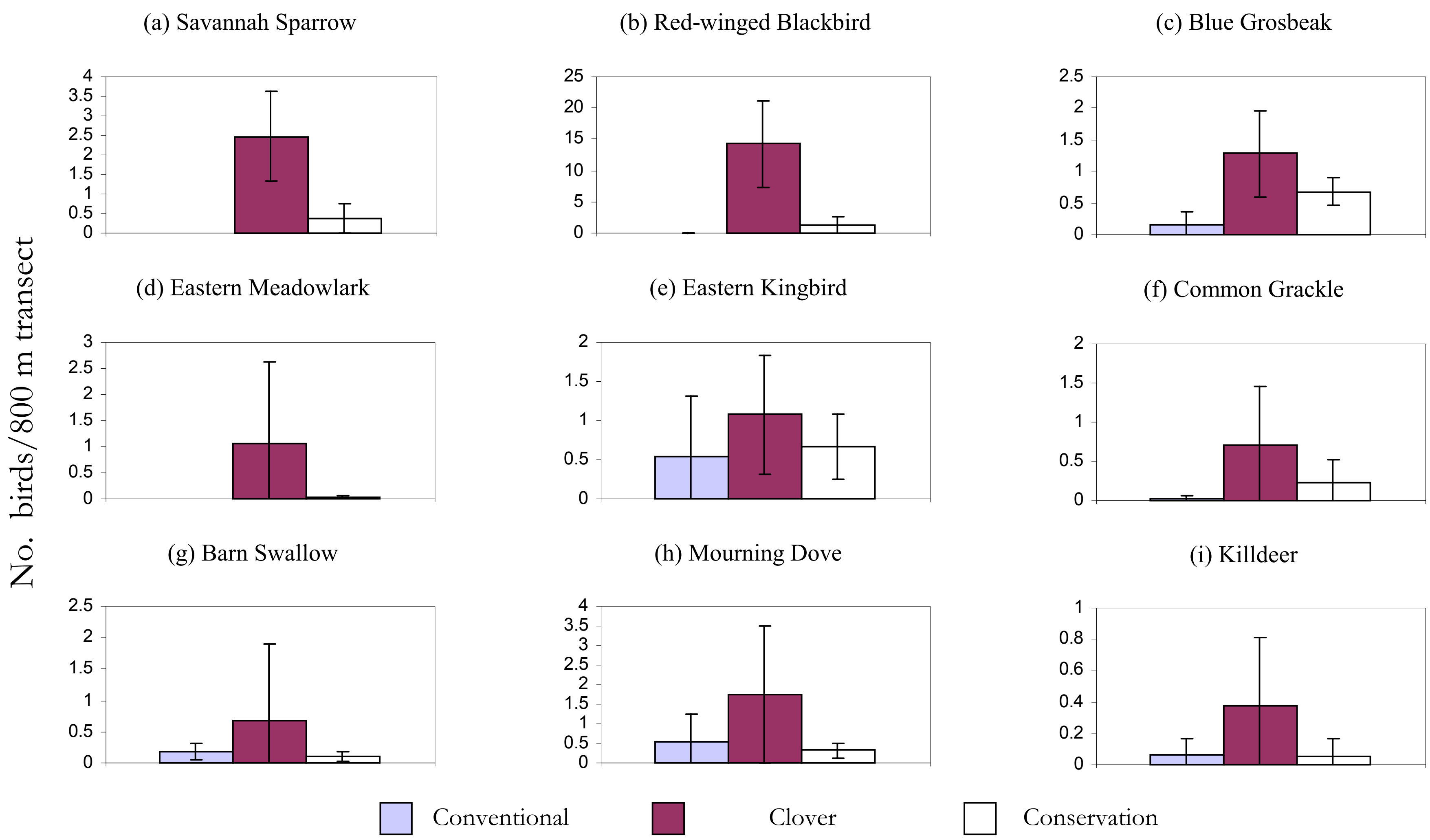


Figure 10. Mean number of detections (± 95% CI) during Breeding of 2000 by (a) Savannah Sparrow, (b) Red-winged Blackbird, (c) Blue Grosbeak, (d) Eastern Meadowlark, (e) Eastern Kingbird, (f) Common Grackle, (g) Barn Swallow, (h) Mourning Dove and, (i) Killdeer on Conventional, Clover, and Conservation cotton fields

During 2000, detections of Blue Grosbeak were significantly higher on Clover and Conservation plots than Conventional plots. Clover plots had the highest detections for Eastern Meadowlark, although there was no significant difference for Clover and Conservation plots. There were no detections on Conventional fields. Detections for Common Grackle Barn Swallow and Killdeer detections were greatest in Clover although not significantly over Conventional and Conservation.

Total number of species detected was much higher in the reduced-tillage treatments with Clover attracting a greater diversity of species during 2000, but there was no real difference in the Shannon-Weiner index due to the elevated levels of individuals on those plots (Appendix B).

## ARTHROPOD SAMPLING

*BIOMASS:* Average total biomass was highest each month in Clover plots although it was only statistically significant during July ($F_{2,18}$=4.73, $P$=0.03) (Figure 11). Conservation and Conventional plots showed similar biomass levels during each sampling period.

Although no MANOVA tests were significant for the biomass analyses of PEST/BEN, the trends in the data suggest an increase on Clover plots over the other two treatments in both PEST and BEN for June and July, with a greater increase in PEST species (Figure 12). During June and July, crickets (Family *Gryllidae*) accounted for most of the PEST biomass (64% and 82%, respectively) on Clover plots, while it held a relatively low proportion of the numbers (6% and 15%, respectively). BEN biomass was dominated by tiger beetles (Family *Cicindelidae*) across all treatments during June and

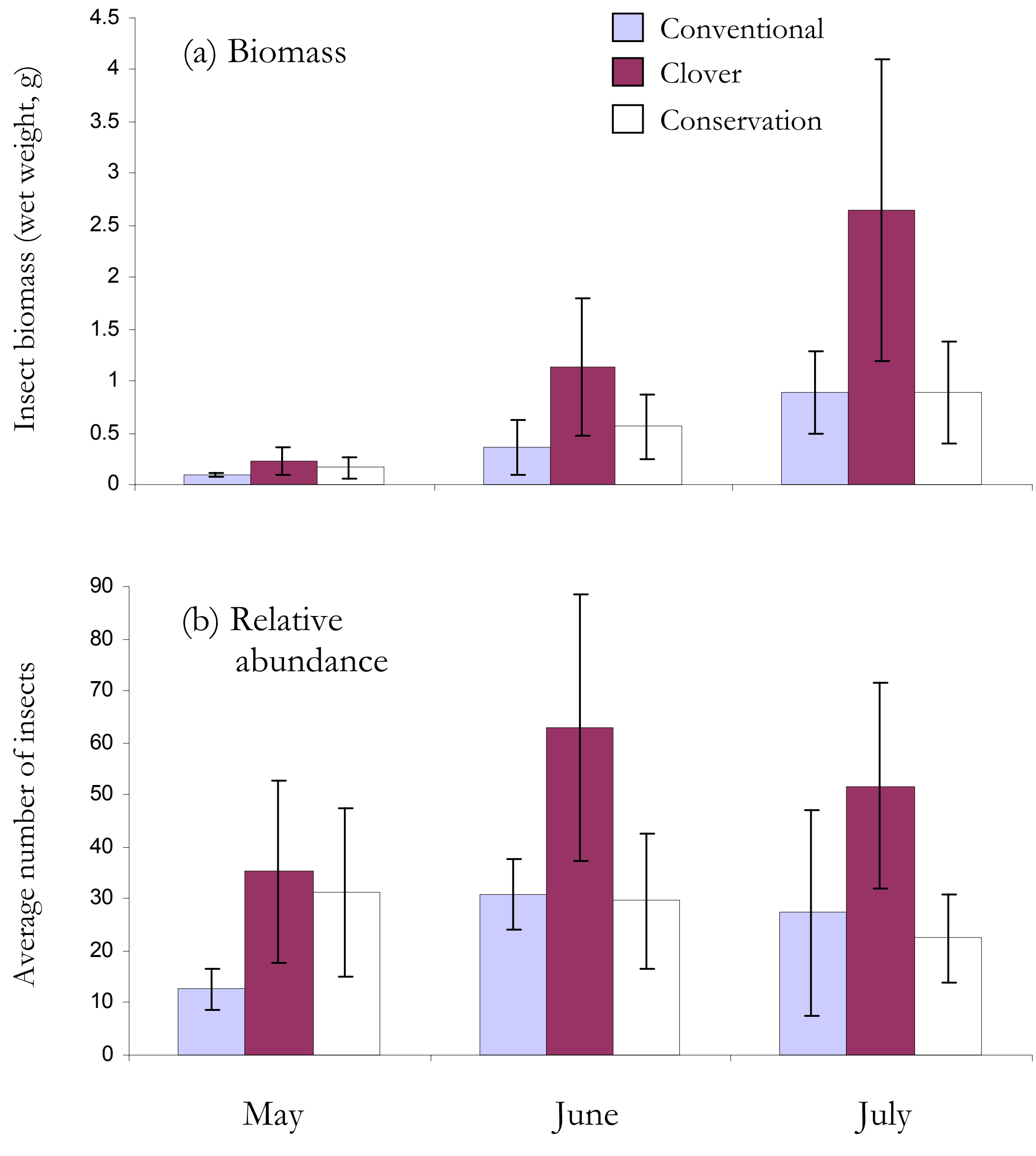


Figure 11. Insect (a) biomass (wet weight, g) and (b) relative abundance (± 95% CI) from pitfall cups in cotton fields in central Georgia, during 1999.

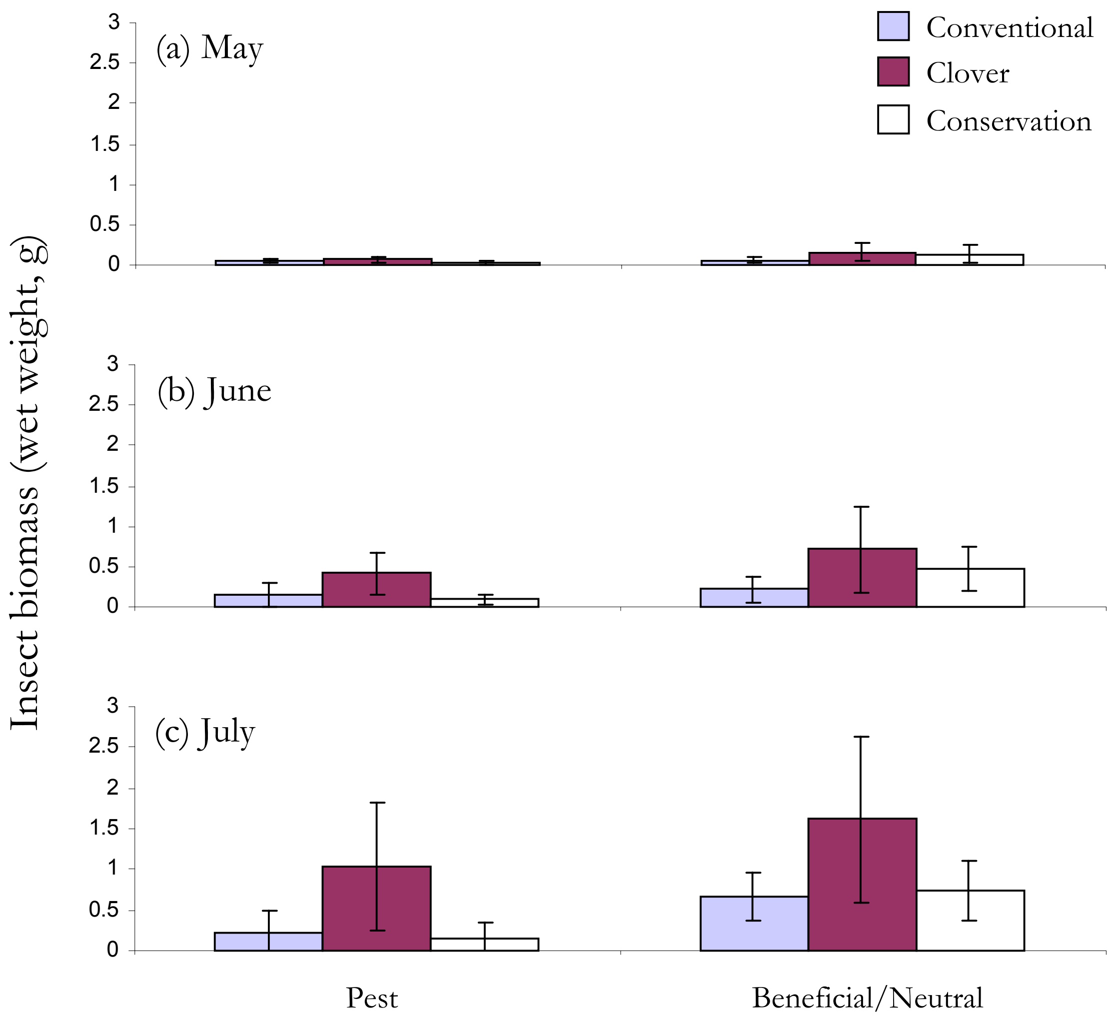


Figure 12. Beneficial/neutral and Pest insect biomass (wet weight, g) (± 95% CI) during (a) May (b) June and (c) July from pitfall cups in cotton fields in central Georgia, during 1999.

July, with the highest biomass and percentage biomass occurring on Clover plots (Table 5). The percent tiger beetles of total numbers remained relatively consistent within a sampling period across treatments.

*Relative Abundance:* Number of individuals were similar between Clover and Conservation treatments during May and elevated over Conventional levels (Figure 11). Catch numbers in Clover were higher than those in Conventional during June, and those in Conservation during both June and July ($F_{2,17}$=4.59, 2 df, $P$=0.03 and $F_{2,18}$=4.4, 2 df, $P$=0.03, respectively). Conservation and Conventional treatments maintained similar levels during June and July.

We found no differences between treatments for PEST or BEN . Despite the non-significant MANOVA levels, BEN trends showed an increased catch for Clover over both Conventional and Conservation during June and July (Figure 13). May counts for BEN revealed similar numbers for Clover and Conservation plots, well above those of Conventional plots, while none was significant. Analyses of PEST species showed little difference between treatments during any sampling period. Fire ants (Family *Myrmicinae*) dominated the BEN catches for all treatments during May and June, and Conventional during July. While numbers of fire ants were still high during July on the remaining treatments, rove beetles (Family *Staphyllinidae*) dominated Clover catches, and the principal taxa on Conservation plots were fire ants, tiger beetles, and sap beetles (Family *Nitidulidae*), all with very similar numbers (Table 6).

Table 5. Insect families which accounted for the highest biomass (wet weight, g) and its percentage of total abundance in pitfall traps in cotton fields in central Georgia, during 1999.

| | | | May | | | June | | | July | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Family | Weight | % Sample | Family | Weight | % Sample | Family | Weight | % Sample |
| **Conventional** | Pest | Biomass | Elateridae | 1.03 | 88.0% | Elateridae | 3.77 | 94.7% | Gryllidae | 4.99 | 87.6% |
| | | Abundance | | 41 | 56.9% | | 165 | 67.6% | | 7 | 5.3% |
| | Beneficial | Biomass | Apidae | 0.40 | 25.1% | Cicindelidae | 2.12 | 34.8% | Cicindelidae | 11.78 | 67.6% |
| | | Abundance | | 1 | 1.4% | | 11 | 1.8% | | 77 | 14.7% |
| **Clover** | Pest | Biomass | Acrididae | 0.94 | 48.3% | Gryllidae | 7.47 | 64.2% | Gryllidae | 22.11 | 81.7% |
| | | Abundance | | 5 | 4.2% | | 19 | 5.6% | | 29 | 14.4% |
| | Beneficial | Biomass | Apidae | 1.95 | 43.9% | Cicindelidae | 11.58 | 57.7% | Cicindelidae | 39.08 | 92.0% |
| | | Abundance | | 9 | 1.0% | | 69 | 4.9% | | 271 | 23.9% |
| **Conservation** | Pest | Biomass | Elateridae | 0.70 | 89.1% | Gryllidae | 0.76 | 35.9% | Gryllidae | 3.15 | 73.3% |
| | | Abundance | | 30 | 53.6% | | 2 | 1.7% | | 2 | 1.9% |
| | Beneficial | Biomass | Arachnida | 1.75 | 49.0% | Cicindelidae | 6.38 | 56.1% | Cicindelidae | 11.89 | 60.1% |
| | | Abundance | | 31 | 4.1% | | 38 | 6.4% | | 82 | 17.2% |

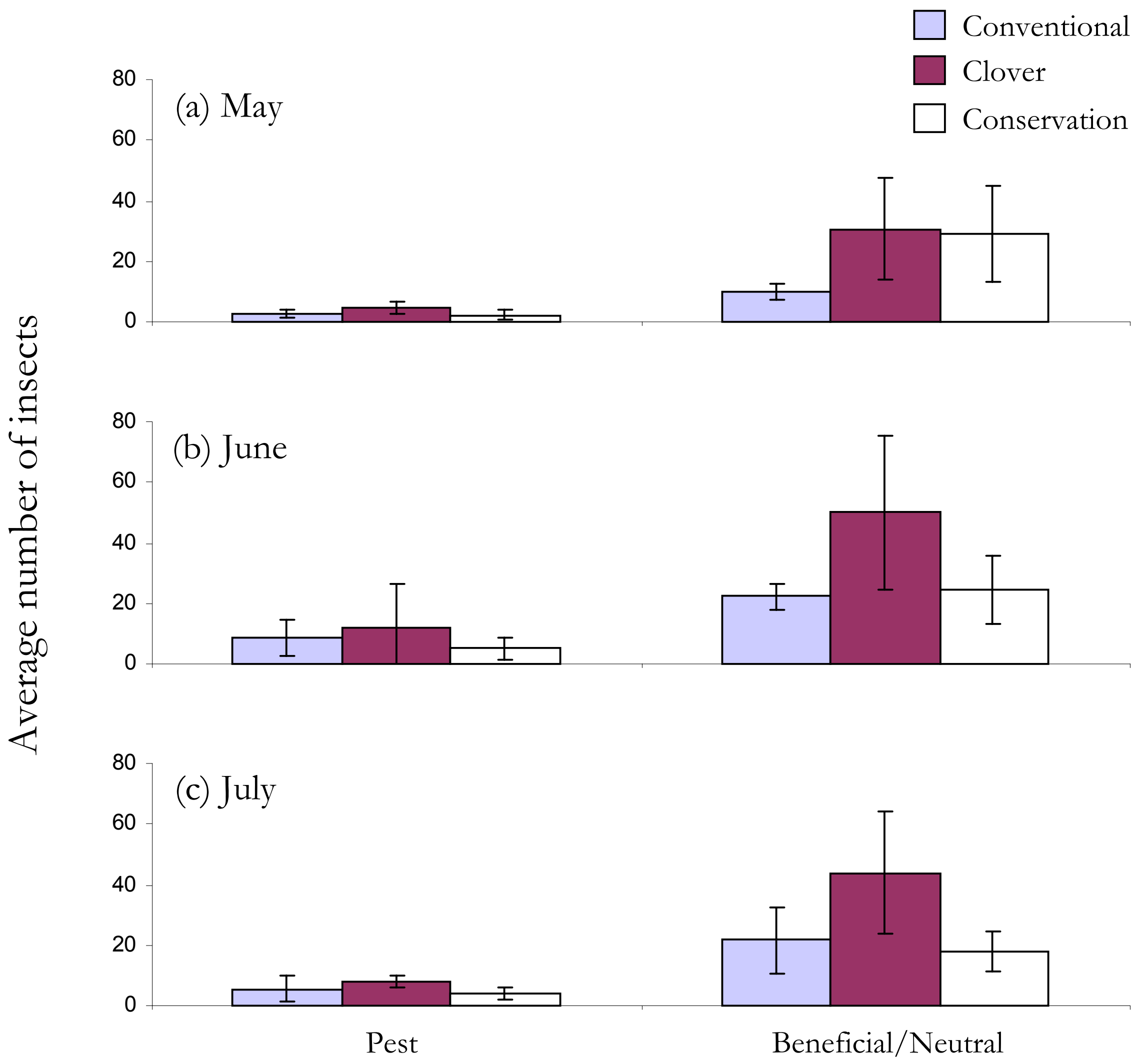


Figure 13. Beneficial/neutral and Pest insect relative abundance (± 95% CI) during (a) May (b) June and (c) July from pitfall cups in cotton fields in central Georgia, during 1999.

Table 6. Insect families which accounted for the highest biomass (wet weight, g) and highest abundance in pitfall traps in cotton fields in central Georgia, during 1999.

| | | | May | | | June | | | July | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Family | Amount | % Sample | Family | Amount | % Sample | Family | Amount | % Sample |
| **Conventional** | Pest | Biomass | Elateridae | 1.03 | 88.0% | Elateridae | 3.77 | 94.7% | Gryllidae | 4.99 | 87.6% |
| | | Abundance | Elateridae | 41.00 | 56.9% | Elateridae | 163.00 | 67.6% | Scarabidae | 60.00 | 45.5% |
| | Beneficial | Biomass | Apidae | 0.40 | 25.1% | Cicindelidae | 2.12 | 34.8% | Cicindelidae | 11.78 | 67.6% |
| | | Abundance | Myrmicinae | 128.00 | 46.0% | Formicinae/ Myrmicinae | 351.00 | 56.5% | Formicinae/ Myrmicinae | 222.00 | 42.4% |
| **Clover** | Pest | Biomass | Acrididae | 0.94 | 48.3% | Gryllidae | 7.47 | 64.2% | Gryllidae | 22.11 | 81.7% |
| | | Abundance | Miridae | 66.00 | 55.5% | Scarabidae | 237.00 | 69.5% | Scarabidae | 48.00 | 23.9% |
| | Beneficial | Biomass | Apidae | 1.95 | 43.9% | Cicindelidae | 11.58 | 57.7% | Cicindelidae | 39.08 | 92.0% |
| | | Abundance | Formicinae/ Myrmicinae | 481.00 | 55.7% | Formicinae/ Myrmicinae | 938.00 | 66.9% | Staphylinidae | 327.00 | 28.8% |
| **Conservation** | Pest | Biomass | Elateridae | 0.70 | 89.1% | Gryllidae | 0.76 | 35.9% | Gryllidae | 3.15 | 73.3% |
| | | Abundance | Elateridae | 30.00 | 53.6% | Scarabidae | 47.00 | 38.8% | Tenebrionidae | 37.00 | 34.6% |
| | Beneficial | Biomass | Arachnida | 1.75 | 49.0% | Cicindelidae | 6.38 | 56.1% | Cicindelidae | 11.89 | 60.1% |
| | | Abundance | Myrmicinae | 517.00 | 69.2% | Myrmicinae | 289.00 | 49.0% | Myrmicinae | 86.00 | 18.0% |

VEGETATION SAMPLING

*CORRELATIONS:* SPARROW species showed a strong positive correlation with COVER and negative correlation with BARE during Winter 2000 (values for all correlations appear in Table 4). Most of those SCRUB species included in these analysis do not generally occur in this area during the winter period (9 out of the 12 species, Appendix A) and only two detections of one wintering species occurred on all plots during this period. Therefore no correlations were run for SCRUB species during the winter. GROUND species showed no strong correlations with any vegetation type.

Since most species included in the SPARROW guild do not breed in this region (6 out of 9), the analysis of transects was truncated when detections for these species dropped off (i.e., survey 4, 15 May 1999; and survey 11, 13 May 2000). Migration was then extended to include the extra surveys (causing the total migration period for SPARROW to include surveys 1-4 during 1999 and surveys 4-11 during 2000). During the extended migration period for both years, strong correlations were detected between number of SPARROWs and BARE (negative) and COVER (positive), but the strongest correlations were found with GREEN (positive). Correlations for all other guilds were run using the original seasons (Table 2). Strong positive correlations were detected for COVER, GREEN , DEAD, HEIGHT (positive) and BARE (negative) and number of birds in the SCRUB guild during 2000, while no strong correlations were detected during 1999. GROUND species showed a strong negative correlation with LITTER during migration for both 1999 and 2000.

Original correlations for the Breeding period were run using all surveys during the breeding period (surveys 3-11 during 1999 and 9-21 during 2000). Upon examination of the correlations vegetation types were not generally correlated with the number of birds. Because songbirds establish territories during the breeding season, it would be less likely that numbers of birds would fluctuate with the changes in percent values for vegetation. Therefore for the correlations were constructed using the early surveys during Breeding when most species would be setting up territories (surveys 3-4 and 9-11 for 1999 and 2000, respectively). During the shortened Breeding period LITTER was positively correlated with bird number for SCRUB species during 1999, whereas in 2000 numbers were positively correlated with GREEN and COVER and negatively correlated with BARE. Vegetation correlations with GROUND species varied between years with strong negative correlations with DEAD, LITTER, and COVER and positive correlation with BARE during 1999 and a positive correlation with GREEN during 2000.

*VEGETATION TYPES:* Although a Complete Block ANOVA revealed a significant blocking effect for GREEN, the treatment effect was not significant. No vegetation types showed significant treatment effects during Winter 2000 (Figure 14, Table 7). Both GREEN and BARE showed a significant treatment effect during Migration 1999 and 2000, with vegetation on the Clover and Conservation tillage plots greater than Conventional plots (Figures 14). DEAD and LITTER values suggested a similar trend between treatments but were not significant (Table 8). Significant treatment effects were detected during Breeding for both 1999 and 2000 for BARE, DEAD, and LITTER. Clover and Conservation tillage plots had higher levels of DEAD and LITTER than Conventional plots during 1999, whereas BARE levels showed the reverse trend. During 2000, BARE values were again significantly higher on Conventional plots while LITTER value were significantly elevated on both Clover and Conservation fields. Values for

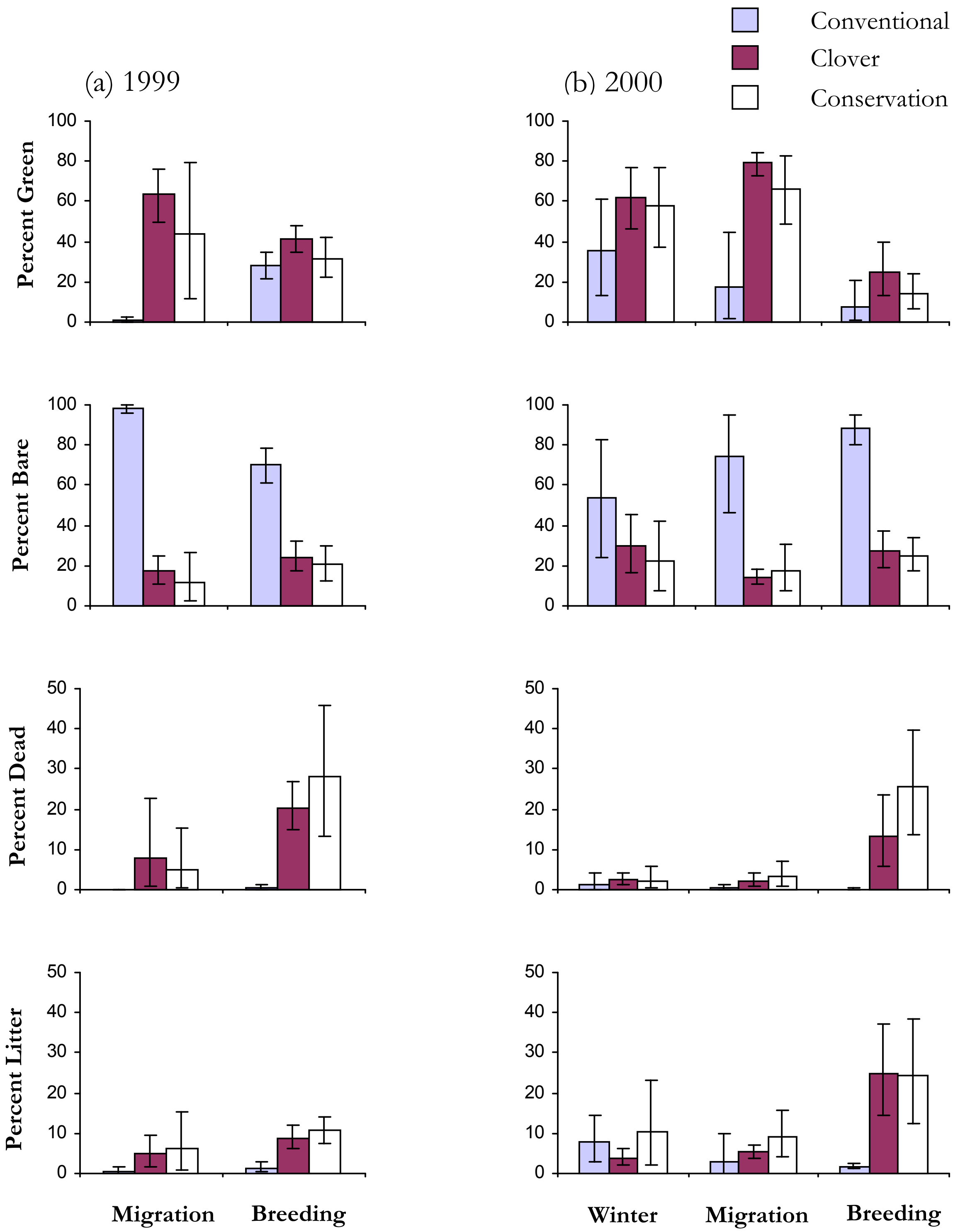


Figure 14 Percent vegetation (± 95% CI) for Green, Bare, Dead, and Litter, during (a) migration, and breeding periods 1999 and (b) winter, migration, and breeding periods 2000 within cotton fields in central Georgia. Breeding periods for 2000 only include fields which continued to be farmed for cotton.

Table 7. Results of ANOVA of vegetation during the winter, migration, and breeding periods within cotton fields in central Georgia, during 1999 and 2000. Breeding periods during 2000, only include fields that were farmed for cotton throughout censuses.

| | | **1999** | | **2000** | | |
|---|---|---|---|---|---|---|
| Vegetation Parameters | | Migration | Breeding | Winter | Migration | Breeding |
| | F | 13.37 | 2.67 | 2.26* | 11.32 | 1.91 |
| **GREEN** | P | 0.003 | 0.0966 | 0.175 | 0.0017 | 0.2423 |
| | df | 2,18 | 2,18 | 7,7 | 2,12 | 2,5 |
| | F | 81.3 | 32.84 | 2.05 | 14.76 | 43.68 |
| **BARE** | P | <0.0001 | <0.0001 | 0.1713 | 0.0006 | 0.0007 |
| | df | 2,18 | 2,18 | 2,12 | 2,12 | 2,5 |
| | F | 3.32 | 18.79 | 0.23 | 2.72 | 9.65 |
| **DEAD** | P | 0.0593 | <0.0001 | 0.7968 | 0.1063 | 0.0192 |
| | df | 2,18 | 2,18 | 2,12 | 2,12 | 2,5 |
| | F | 3.28 | 19.19 | 0.88 | 1.73 | 40.16 |
| **LITTER** | P | 0.0608 | <0.0001 | 0.439 | 0.2186 | 0.0008 |
| | df | 2,18 | 2,18 | 2,12 | 2,12 | 2,5 |

* GREEN during Winter 2000 had a significant block effect. The treatment value is recorded.

Table 8. Mean percent vegetation density coverage (± 95% CI) for each season in central Georgia during 1999 and 2000.[2]

| | | Treatment[1] | %Mean | %Low | %High |
|---|---|---|---|---|---|
| **Migration 1999** | | | | | |
| | Green | C | 0.46 | 0.02 | 2.25 |
| | | L | 63.31 | 49.27 | 76.28 |
| | | N | 43.52 | 11.16 | 79.44 |
| | Bare | C | 98.42 | 95.85 | 99.78 |
| | | L | 17.22 | 10.56 | 25.10 |
| | | N | 11.86 | 2.51 | 26.82 |
| | Dead | C | 0.01 | 0.01 | 0.09 |
| | | L | 8.03 | 0.64 | 22.56 |
| | | N | 5.02 | 0.27 | 15.14 |
| | Litter | C | 0.46 | 0.01 | 1.54 |
| | | L | 4.90 | 1.70 | 9.63 |
| | | N | 6.25 | 1.03 | 15.43 |
| **Breeding 1999** | | | | | |
| | Green | C | 28.19 | 21.75 | 35.12 |
| | | L | 41.11 | 34.68 | 47.69 |
| | | N | 31.54 | 22.06 | 41.86 |
| | Bare | C | 69.88 | 60.81 | 78.23 |
| | | L | 24.31 | 17.35 | 32.03 |
| | | N | 20.42 | 12.18 | 30.16 |
| | Dead | C | 0.43 | 0.06 | 1.12 |
| | | L | 20.33 | 14.67 | 26.66 |
| | | N | 27.93 | 13.09 | 45.81 |
| | Litter | C | 1.26 | 0.31 | 2.83 |
| | | L | 8.88 | 6.26 | 11.92 |
| | | N | 10.69 | 7.59 | 14.24 |
| **Winter 2000** | | | | | |
| | Green | C | 35.36 | 13.35 | 61.31 |
| | | L | 62.18 | 46.18 | 76.91 |
| | | N | 57.63 | 36.82 | 77.12 |
| | Bare | C | 53.88 | 23.92 | 82.37 |
| | | L | 30.16 | 16.72 | 45.61 |
| | | N | 22.22 | 7.45 | 42.01 |
| | Dead | C | 1.30 | 0.06 | 4.07 |
| | | L | 2.35 | 1.05 | 4.15 |
| | | N | 2.18 | 0.31 | 5.66 |
| | Litter | C | 7.66 | 2.82 | 14.59 |
| | | L | 3.90 | 2.01 | 6.39 |
| | | N | 10.20 | 2.19 | 23.13 |

Table 8. Continued

| | Treatment[1] | %Mean | %Low | %High |
|---|---|---|---|---|
| **Migration 2000** | | | | |
| Green | C | 17.59 | 1.84 | 44.42 |
| | L | 78.98 | 73.02 | 84.38 |
| | N | 66.52 | 48.59 | 82.28 |
| Bare | C | 74.69 | 45.97 | 94.87 |
| | L | 13.94 | 10.36 | 17.96 |
| | N | 17.13 | 7.11 | 30.35 |
| Dead | C | 0.37 | 0.01 | 1.27 |
| | L | 2.21 | 0.88 | 4.12 |
| | N | 3.36 | 0.97 | 7.14 |
| Litter | C | 2.98 | 0.08 | 9.81 |
| | L | 5.20 | 3.72 | 6.91 |
| | N | 9.10 | 4.13 | 15.77 |
| **Breeding 2000** | | | | |
| Green | C | 7.62 | 0.84 | 20.32 |
| | L | 25.09 | 13.04 | 39.51 |
| | N | 14.23 | 6.73 | 23.93 |
| Bare | C | 88.39 | 79.89 | 94.79 |
| | L | 27.54 | 18.76 | 37.31 |
| | N | 25.15 | 17.44 | 33.75 |
| Dead | C | 0.15 | 0.02 | 0.41 |
| | L | 13.30 | 5.69 | 23.46 |
| | N | 25.46 | 13.45 | 39.76 |
| Litter | C | 1.83 | 1.22 | 2.57 |
| | L | 24.86 | 14.42 | 37.04 |
| | N | 24.31 | 12.56 | 38.46 |

[1] Treatments: C, Conventional; L, Clover; N, Conservation

[2] Percentages are transformed back from square root arcsign for comparison purposes

DEAD were significantly higher on Conservation tillage plots than Conventional and effect sizes suggested a similar trend for differences between Clover and Conventional. The only vegetation parameter that was not different among treatments for the whole breeding period in either year was GREEN. By late in the breeding season most cover crops died back or had been chemically suppressed. As all fields were planted to cotton, the treatments would be relatively similar in the amount of green vegetation growing on the fields.

# DISCUSSION

The rapid intensification of agricultural areas as well as loss of land to pine-plantation farming, urbanization, and succession have altered the availability of appropriate habitat for early successional avian species in the Southeast. Alterations to current agricultural practices, designed to decrease environmental problems associated with annual crop production, such as erosion and pesticide runoff, could also have an immediate reversing effect on negative avian trends. Initiation of a winter cover crop provides needed cover for avian species currently lacking in conventional agriculture during winter and migration periods. Additionally the cover crop, particularly one which hosts a diverse and populous insect community, provides protection against phytophagous insects for the incoming crop by increasing the predatory and parasitic insect community well before the crop is initiated. This also creates a dense food supply for songbirds throughout the migration and breeding periods. Coupled with a reduction in tillage, the variation in structure provided by relay intercropping increases protection from predation while feeding or nesting and reduces nest destruction due to plowing, and may thereby allow for greater field use by songbirds.

In Georgia, plowing of Conventional fields to prepare seed beds for cotton begins in early to mid-March and continues through planting in early to mid-May. This time period spans the late winter to early breeding season, ensuring that the land is less desirable for migrating and resident bird species due to reduced vegetative cover and food supply. The analysis of percent vegetation for Winter 2000 showed large deviations between Conventional fields and reduced tillage (Clover and Conservation) treatments for both GREEN and BARE (negatively correlated variables, N=9, R=-0.8663, p=0.0025). Conventional fields had a much higher percentage of BARE and consequently a much lower level of GREEN then the other two treatments. These winter surveys also included periods prior to plowing. Although the inclusion of pre-plow surveys lead to a high variability in percentage vegetation, a large difference was still detected. During this period, 72% of all avian clusters detected, across all treatments were included in the SPARROW guild. Positive correlations of both GREEN and HEIGHT with numbers of SPARROWs, along with the strong negative correlation with BARE show these factors to be important in determining avian field use during this period. Detections of SPARROW clusters were 4-10 times higher on Clover and Conservation treatments over Conventional fields, while ALL species ranged 3-7 times higher. Individual species analysis for Savannah Sparrows showed a similar elevated trend for reduced tillage fields, while Eastern Meadowlark numbers were highest on the Clover treatment and entirely absent on Conventional fields. Other studies documenting winter avian field use of agricultural areas have also detected higher densities on treatments with increased cover (Castrale 1985, Flickinger and Pendleton 1994).

We attributed similar bird densities detected in the winter for both Clover and Conservation treatments to the comparable vegetation found on the two treatments. Insect densities are not available for this period and, therefore, inferences cannot be made about the influence of arthropods on avian densities. However, most songbirds detected on our plots during the winter are primarily granivorous during this period and, therefore, may not be influenced as strongly by insect abundance as in later seasons. Multiple studies have shown an increased concentration of weed seeds in the upper soil levels with decreased tillage (Yenish et al. 1992, Sahoo et al. 1995, Clements et al. 1996, Hoffman et al. 1998). Consequently the protection afford by cover crops as well as the increased weed seed availability due to reduced tillage on both the Clover and Conservation treatments allowed for similar and increased avian densities as compared to Conventional treatments.

Habitat disruption due to agricultural activities is also important for migrating songbirds. During Migration periods for both 1999 and 2000, Conventional fields were the only treatment receiving cultivation. Consequently vegetation analysis between treatments exhibited extreme differences for BARE and GREEN between Conventional plots and the other two reduced tillage treatments. During both years Conventional plots maintained less than 25% (less than one% in 1999) as much GREEN and 4-8 times the amount of BARE as Clover or Conservation treatments. These vegetation parameters were correlated (positive with GREEN and/or negative for BARE) with number of birds in each behavioral guild except GROUND, which were instead negatively correlated with the amount of LITTER. Mourning Doves accounted for 73% of GROUND species detected (30% of which occurred in one flock) during Migration 1999. Mourning Doves feed primarily in open ground, but do not probe or scratch for food. Areas of heavy litter or high, dense vegetation are generally avoided during foraging (Mirarchi and Baskett 1994). During this same period BARE levels reached 100% for Conventional fields. Not surprisingly, Mourning Doves were the only species in which Conventional fields had greater detections.

In a comparison of minimum tillage, conventional, and organic fields in North Dakota, Lokemoen and Beiser (1997) found higher avian densities during the spring on minimum-tillage fallow fields due to the increased cover and available food found on the unplowed fields. Our individual species analysis for Savannah Sparrows and Red-winged Blackbirds showed similar trends with elevated detection levels on reduced tillage plots and few to no detections on Conventional fields during 1999, with both of the corresponding guilds showing a negative correlation with BARE. Increased densities were also seen for the reduced tillage treatments in the behavioral guild ALL, while Conventional fields lacked enough detections to determine a density. During 2000, all individual species analyzed showed much higher detections on Clover over Conservation plots while Conventional plots had practically no detections. Three out of the four individual species were members of the SPARROW or SCRUB guild which both showed high positive correlations with both GREEN and COVER, which in turn were significantly higher on both Clover and Conservation treatments. Density for ALL species during 2000 was again exceedingly higher for Clover fields over both Conservation and Conventional treatments. So despite similar values for vegetation parameters for both reduced tillage treatments, Clover fields attracted a much higher densities of songbirds.

During Migration, management of Clover and Conservation treatments were similar aside from the application of cover crop. All Clover fields maintained a cover of clover throughout the winter and spring while the cover crop use varied on Conservation fields. Four out of seven and three out of five Conservation fields had a winter wheat cover crop during 1999 and 2000, respectively, while the remaining maintained weedy cover. In an Oklahoma study, beneficial insect populations in clover cover crops showed increases as early as March (although no samples were taken during January or February) and populations were harbored for nearly the entire year (French et al. 2001). In a comparison of clover and weed cover in California cornfields, the beneficial insect load was elevated on clover plots for foliage dwelling insects while both covers allowed for similar epigeal predator populations (Altieri et al. 1985). During spring, levels of arthropods begin to increase in the resident songbird diet and insectivorous migrants begin to arrive. Bollinger and Clark (1985) found that early during the season Red-winged Blackbird presence was influenced by rootworm populations in cornfields, with high levels of Red-wing Blackbirds positively correlated with rootworm numbers. Similarly, Roland et al (1986) found that the density and foraging time of Pine Siskins (*Carduelis pinus*) were positively correlated with the abundance of the winter moth larvae (Lepidoptera: *Operophtera brumata*) in apple orchards (In Kirk 1996). Greater insect densities have been found in flowering plants due to the availability of nectar (Landis et al. 2000). Although arthropods on our plots were not sampled during Migration, flowering began on Clover plots in late winter and continued through the early breeding season. This available nectar would likely attract increased arthropod levels and consequently provide an ample food source for songbirds and may therefore explain the higher density of songbirds found on the Clover treatment.

Due to the continuation of the drought during 2000 and the increased possibility of crop loss, many farmers did not manage their field as intensively as in past years. This decrease in intensity lead to weedy conventional fields and caused increased GREEN and decreased BARE levels during the migration period. Although the increased weediness caused a decrease in the dissimilarity of the treatments for both vegetation and avian parameters, it did not effect the significance levels of the elevated reduced-tillage treatments. We would therefore expect to see even greater differences in avian, arthropod, and vegetative make-up within the fields during non-drought years.

Due to differences in field operations between the Conventional fields and reduced-tillage fields, we again detected significant variations in percent vegetation during the Breeding seasons. Levels of BARE, are extremely disjunct between Conventional and reduced-tillage fields and consequently the levels of DEAD and LITTER are much higher on Clover and Conservation fields. GROUND and SCRUB guilds were negatively correlated with BARE (and positive correlated with GREEN) during 2000, while during 1999 GROUND species showed an extreme negative correlation with DEAD, LITTER, and COVER while exhibiting a positive correlation with BARE. The yearly variation for GROUND is attributed to the makeup of species during each year. Mourning doves made up 66% of the total individuals during 1999, primarily due to one large flock (24 making up 30% of all Mourning Doves), while that percentage dropped to 38 during 2000 and the difference was composed primarily of Eastern Meadowlarks. As opposed to the open, litter free area in which Mourning Doves prefer to forage, Eastern Meadowlarks commonly occupy early successional habitat with decent herbaceous vegetation and litter cover (Lanyon 1995). Correlations for SCRUB during 1999 are less explicative as avian densities are only mildly positively correlated with LITTER.

Analogous tillage and management options throughout the Breeding periods for the reduced-tillage plots maintained similar levels of all vegetation parameters for the season as a whole, yet avian detections were consistently higher for all individual species on Clover plots except for Eastern Kingbird and Mourning Dove in 1999. Again higher Mourning Dove numbers on Conventional fields were attributed to impoverished site preferences for adults, whereas the increased numbers on Conservation fields for Eastern Kingbirds was due to a single large flock (36 individuals) during the first sampling week of the breeding season. If this remnant migrating flock is removed, detections in the Clover treatment were over two times that of the Conservation treatment. Densities for GROUND and ALL species also showed higher levels for the Clover treatment for both years, while SCRUB species levels were higher in 2000 only. The lower density for SCRUB in 1999 again was due in part to the large Eastern Kingbird flock and the lower sample size during 1999. Comparisons of avian field use in different crops found clover hosted 30% more species then wheat (Graber and Graber 1963). Clover fields also supported higher avian densities (6.9-10.1 birds/ha) than both fallow fields (4 birds/ha) and grassland habitat (5.4 birds/ha) while wheat provided relatively poor habitat which attracted far fewer (2.2) birds per hectare. While these densities are much higher than those detected on our fields, the proportion of bird densities we found on Clover (3.2 times higher averaged over both years) compared to Conservation is similar. If all other parameters are consistent so that the two field types afford the same level of cover and protection, one would then assume elevated avian levels are due to a variation in available food resources.

Relative insect abundance levels were dramatically elevated on both reduced tillage treatments, Conservation and Clover, over Conventional plots during the early breeding season. Habitat disturbance has been shown to temporarily lower predator activity and predation, with levels beginning to recover after three weeks (Brust et al. 1986b). The May sampling period occurred during or just after most plots had been planted so Clover and Conservation treatments may have had similar relative abundance at that time due the strip-till method of cultivation which occurred on both treatments. Conventional plots had also just been planted but tillage had begun about two months earlier and continually buried all crop and weed residue. Previous studies comparing the effects of various levels of tillage on insect populations have echoed the enhanced insect populations we found on reduced tillage plots (Blumberg and Crossley 1983, House and Stinner 1983, Warburton and Klimstra 1984). Increased insect abundance has been attributed to an increase in cover (Warburton and Klimstra 1984, Honek 1997), food supply (Blumberg and Crossley 1983, Honek 1997), favorable microclimate (Warburton and Klimstra 1984, Honek 1997), and increased over winter survival (Warburton and Klimstra 1984). The elevated insect abundance on our reduced tillage treatments was due entirely to beneficial insects. Beneficial populations were much lower on Conventional treatments, where COVER was only 11% compared to 64 and 56% for Clover and Conservation, respectively. The level of soil tillage has been shown to affect the species diversity and abundance of predatory insects, with lower tillage levels hosting more beneficial insects (House and All 1981, Blumberg and Crossley 1983, House and Stinner 1983, Brust et al. 1985, Honek 1997). The elevated insect abundance achieved through the use of reduced tillage, and perhaps cover crop, during May for Conservation fields was lost by the mid-breeding period, while Clover remained high. After this point the abundance and biomass, for overall and PEST/BEN, found on Conservation plots became very similar to that of the Conventional fields.

Management practices that create vegetative growth early in the season are favorable for most predatory insects (Booij and Noorlander 1992, Letourneau and Goldstein 2001). These winter cover crops also aid in the over wintering survival of many predators due to the availability of alternative food sources (e.g., nectar, insects, pollen) and suitable microclimate (van Emden 1989, Phatak 1998, Landis et al. 2000, Letourneau and Goldstein 2001). Whether a cover crop is incorporated into the soil or left standing, live or dead, has great implications for the beneficial insect population. When an entire cover crop is treated with an herbicide or incorporated into the soil, the food source for the beneficial insects is removed (Phatak 1998). If instead, an alternative food source (i.e., the pest insects on a cotton plant) becomes available as the remaining cover crop begins to wither, as in the Clover treatment, the beneficial insects can maintain population levels as they transfer to the new food source (Parajulee et al. 1997, Phatak 1998). Parajulee (1997) found the resulting predator populations in cotton were elevated in relay intercropped cotton over those in conventional cotton. In a study comparing aphid and beneficial species of multiple crop types, French et al (2001) found no aphid species from clover were found in the cotton. However, clover attracted *Trioxys* species, a known parasitoid of the cotton aphid (*Aphis gossypii*), and many of the same predator species. Multiple studies comparing monocultures with intercropped fields have detected higher arthropod numbers in the diversified intercropped fields (Altieri and Whitcomb 1979, Blumberg and Crossley 1983, Brust et al. 1986a, Parajulee and Slosser 1999). In addition, Brust et. al (1986a) observed higher attack rates by beneficial insects on Lepidoptera larva in the intercropped system, while Parajulee (1999) found increased aphid levels in cotton monocultures compared to intercropped systems. Booij et al

(1997) found higher activity-densities of Carabidae in cabbage intercropped with clover than compatible conventional plots.

Insect response began to vary between Clover and Conservation plots in the months following tillage (June and July), suggesting that these levels were influenced by something other than tillage levels. When vegetation measurements were analyzed by month, we found that the percentage of cover was similar between Clover and Conservation treatments during each month, but the proportion of GREEN changed as the season progressed (Figure 15). Although insects can subsist on dying or dead vegetation for a short period, beneficial insect levels decrease due to diminishing alternative food sources. During April, levels of GREEN were similar for both reduced tillage treatments, but by May Clover plots far exceeded that of both Conventional and Conservation plots, but the insect levels on the Clover and Conservation plots were similar. By June, all three treatments had similar levels of GREEN, due to the growth of the cotton crop, but Clover insect levels, specifically beneficial insects, surpassed that of the other plots. So despite the equally high levels of GREEN and presumably high insect abundance allotted by the cover crop on Conservation plots during April, the residual elevated insect levels seen in May were lost due to the lack of overlap of green vegetation between the cover crop and the cotton. Later in the Breeding period Clover dominated both Conservation and Conventional plots in both insect biomass and abundance, although variations occurring between plots allowed for large confidence intervals. Although the elevated levels of biomass during the latter part of the Breeding season for Clover contained higher levels of PEST as well as BEN, the abundance levels showed the increase entirely due to BEN. Orthoptera, which accounted for most of the dissimilarity

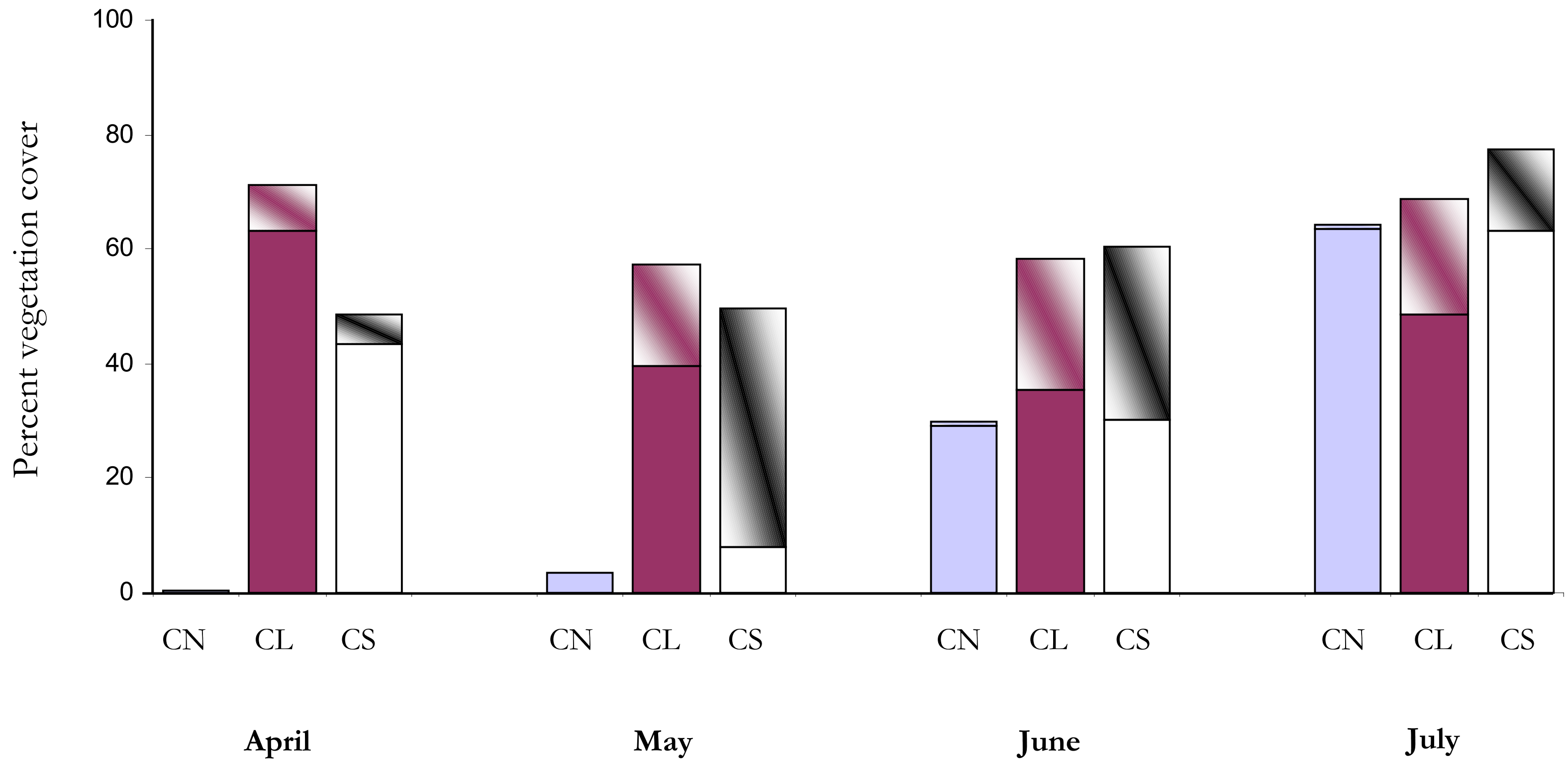


Figure 15. Percent vegetation cover ( ± 95% CI) by month during migration and breeding periods within cotton fields in central Georgia, during 1999. Treatments consisted of conventional (CN), clover stripcover cropping (CL), and conservation tillage (CS). Solid bars are the percentage GREEN, while diagonal stripes represent the percentage DEAD, which together total the percentage of available COVER.

in Clover, made up 77% and 86% of the total pest biomass during June and July, respectively, yet only accounted for 8.8% and 18.4% of the relative abundance during the same time periods. Orthoptera are a primary food source for many songbirds nesting in and around arable land. This late summer increase is typical for Orthoptera and becomes an increasingly important food source for avian species of grassland areas (Maher 1979, Wiens and Rotenberry 1979, Kaspari and Joern 1993). Wiens and Rotenberry (1979) found that Orthoptera accounted for almost one third the total dry weight of food contents from adult insectivous birds during the breeding season, while Maher (1979) found that Orthoptera populations rose throughout the summer months and became increasingly predominate in the nestling diet. Our pitfall sampling detected a similar trend across all treatments. Orthoptera accounted for less than 1% arthropod biomass during May for both Conservation and Conventional treatments and rose to 28% and 18% , respectively, by July. While the biomass on Clover plots increased as well, levels in May were already much higher than the other treatments at 21% then climbed to 34% by July. The larger size and increased availability provided a food source of high nutrition with a low energy expenditure during a period of increased nestling and fledgling population. Kaspari and Joern (1993) found grassland species preferentially selected Acrididae (Order: Orthoptera) over the more numerous (and highly chitinous) Homoptera and as Acrididae increased during the season the percentage consumed increased as well. The reduced chitin in Acrididae provides a higher percentage of nutrients per gram compared to most other families measured. Although Orthoptera is considered a minor pest species in limited regions of the U.S., damage levels in the Southeast are relatively low and abundance levels within our fields were not excessive.

Coleoptera and Lepidoptera are also dominant components of the grassland bird diet (Wiens and Rotenberry 1979, Kaspari and Joern 1993). Coleoptera made up an important proportion of the arthropod population throughout the summer, with similar proportions across treatments although Conventional and Conservation populations are comprised primarily of pest species. Since pitfall traps do not adequately sample Lepidoptera larvae, comparisons cannot be drawn between treatments for pest levels or resource availability. Maher (1979) found elevated proportions of Lepidoptera in the nestling diets of multiple species in the early breeding season when Orthoptera levels were low. As the breeding season progressed, despite equivalent or higher levels of Lepidoptera, Orthoptera accounted for a higher percentage of the nestling diet for most avian species sampled. Comparisons between Lepidoptera larvae and Acrididae have shown much lower chitin levels in Acrididae (Kaspari and Joern 1993), and may have led to the preferential choice.

# CONCLUSION

It is well documented that field size negatively affects the degree of field use by birds (Best et al. 1990, Freemark and Kirk 2001). Avian detections follow a linear decrease as distance from borders increase (Best et al. 1990), with field use concentrated near the border where protective cover exists. Increased heterogeneity is also linked to increased bird abundance and species richness (Freemark and Kirk 2001). Relay intercropping allows for the increased heterogeneity of borders to be brought into field centers, thereby increasing the usable bandwidth into a region previously inaccessible for avian field use. This extension of habitat has occurred temporally as well as spatially, as the winter cover crop provides structure that is lacking in current conventional systems during the winter and migration periods.

The increased diversity found in the Clover and Conservation systems is also a key factor to increasing arthropod field use, as the abundance and diversity of predatory insects in an agronomic system depends not only on the reduction of the pesticides but also on the management system and crop (Baguette and Hance 1997). The distance a beneficial insect can disperse from the alternative plant to the crop is also an important issue. Multiple studies have shown increase predator levels in crop edges, due to the proximity to diversified field borders, compared with the interior of the crop (van Emden 1965, Altieri and Todd 1981, citations within Altieri and Letourneau 1982). The inclusion of live clover into the growing period of cotton increased levels of insects found within the fields, as the availability of habitat prior to and during crop initiation allows for the transfer of these populations to the crop system and thereby maintaining elevated levels throughout the breeding period. This transfer then benefits both the crop and the avian population as high levels of beneficial insects as well as cover are maintained. As avian predation may enhance the dampening effect of beneficial insects in the control of crop pests, heightened avian populations would benefit the grower as well.

The Clover system integrates heterogeneity within the field boundaries allowing for a more natural agroecosystem that can benefit the grower as well as the inhabitants of the system. With this system, a variety of vegetables and cotton have been grown without the use of pesticides (with the exception of Glyphosate used to kill out strips of clover prior to planting)(Phatak 1993, Yancy 1994). It is important to note that although the Clover treatment attracted the highest avian and arthropod densities, Conservation fields still provided increased wildlife and agronomic benefits as compared to Conventional management but due to the variation in management of the two reduced-tillage treatments, the Clover system provided superior habitat. The reduction of input, in the Clover system, coupled with similar or increased yield over conventional systems (Phatak et al. 1999) makes this system not only a good choice for reducing negative impacts on wildlife and surrounding ecosystems, but also a desirable one.

## LITERATURE CITED

Altieri, M. A. and D. K. Letourneau. 1982. Vegetation management and biological control in agroecosystems. Crop Protection 1:405-430.

Altieri, M. A. and J. W. Todd. 1981. Some influences of vegetational diversity on insect communities of Georgia soybean fields. Protection Ecology 3:333-338.

Altieri, M. A. and W. H. Whitcomb. 1979. Potential use of weeds in the manipulation of beneficial insects. Hortscience 14:12-18.

Altieri, M. A., R. C. Wilson, and L. L. Schmidt. 1985. The effects of living mulches and weed cover on the dynamics of foliage-arthropod and soil-arthropod communities in 3 crop systems. Crop Protection 4:201-213.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Pages 1-34 *in* D. M. Power, editor. Current Ornithology. Plenum Press, New York.

Baguette, M. and T. Hance. 1997. Carabid beetles and agricultural practices: influence of soil ploughing. Biological Agriculture & Horticulture 15:185-190.

Basore, N. S., L. B. Best, and J. B. Wooley. 1986. Bird nesting in Iowa no-tillage and tilled cropland. Journal of Wildlife Management 50:19-28.

Bent, A. C. 1965. Life Histories of North American Blackbirds, Orioles, Tanagers, and Allies. Dover Publications, New York.

Best, L. B., K. E. Freemark, J. J. Dinsmore, and M. Camp. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. American Midland Naturalist 134:1-29.

Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of cornfields by birds during the breeding-season - the importance of edge habitat. American Midland Naturalist 123:84-99.

Blumberg, A. Y. and D. A. Crossley. 1983. Comparison of soil surface arthropod populations in conventional tillage, no-tillage, and old field systems. Agro-Ecosystems 8:247-253.

Boatright, S. R. and D. C. Bachtel (Eds.) 1999. The Georgia County Guide. Rural Development Center, Cooperative Extension Service, University of Georgia, Athens, Georgia.

Bollinger, E. K. and J. W. Caslick. 1985. Red-winged Blackbird predation on northern corn-rootworm beetles in field corn. Journal of Applied Ecology 22:39-48.

Booij, C. J. H. and J. Noorlander. 1992. Farming systems and insect predators. Agriculture Ecosystems & Environment 40:125-135.

Booij, C. J. H., J. Noorlander, and J. Theunissen. 1997. Intercropping cabbage with clover: effects on ground beetles. Biological Agriculture & Horticulture 15:261-268.

Bottrell, D. G. and P. L. Adkisson. 1977. Cotton insect pest management. Annual Review of Entomology 22:451-481.

Brust, G. E., B. R. Stinner, and D. A. McCartney. 1985. Tillage and soil insecticide effects on predator black cutworm (Lepidoptera, Noctuidae) interactions in corn agroecosystems. Journal of Economic Entomology 78:1389-1392.

Brust, G. E., B. R. Stinner, and D. A. McCartney. 1986a. Predation by soil inhabiting arthropods in intercropped and monoculture agroecosystems. Agriculture Ecosystems & Environment 18:145-154.

Brust, G. E., B. R. Stinner, and D. A. McCartney. 1986b. Predator activity and predation in corn agroecosystems. Environmental Entomology 15:1017-1021.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall, London, UK.

Bugg, R. L., S. C. Phatak, and J. D. Dutcher. 1990. Insects associated with cool-season cover crops in southern Georgia - implications for pest-control in truck-farm and pecan agroecosystems. Biological Agriculture & Horticulture 7:17-45.

Bugg, R. L., F. L. Wackers, K. E. Brunson, J. D. Dutcher, and S. C. Phatak. 1991. Cool-season cover crops relay intercropped with cantaloupe - influence on a generalist predator, *geocoris-punctipes* (Hemiptera, Lygaeidae). Journal of Economic Entomology 84:408-416.

Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monographs 7-202.

Campbell, L. H., M. I. Avery, P. Donald, A. D. Evans, R. E. Green, and J. D. Wilson. 1997. A review of the indirect effects of pesticides on birds. JNCC Report. 227. Joint Nature Conservation Committee, Peterborough.

Carey, M., D. E. Burhans, and D. A. Nelson. 1994. Field Sparrow. The Birds of North America 103:19 p.

Castrale, J. S. 1985. Responses of wildlife to various tillage conditions. Transactions of the North American Wildlife and Natural Resources Conference 50:142-156.

Chamberlain, D. E. and R. J. Fuller. 2000. Local extinctions and changes in species richness of lowland farmland birds in England and Wales in relation to recent changes in agricultural land-use. Agriculture, Ecosystems & Environment 78:1-17.

Christensen, L. A. and R. S. Magleby. 1983. Conservation tillage use. Journal of Soil and Water Conservation 38:156-157.

Clark, M. S., S. H. Gage, and J. R. Spence. 1997. Habitats and management associated with common ground beetles (Coleoptera: Carabidae) in a Michigan agricultural landscape. Environmental Entomology 26:519-527.

Clements, D. R., D. L. Benoit, S. D. Murphy, and C. J. Swanton. 1996. Tillage effects on weed seed return and seedbank composition. Weed Science 44:314-322.

Conservation Technology Information Center. National crop residue management survey. 2001. October 2001. Viewed on 15 November 2001. http://www.ctic.purdue.edu/CTIC/CTIC.html.

Corbett, A. and R. E. Plant. 1993. Role of movement in the response of natural enemies to agroecosystem diversification - a theoretical evaluation. Environmental Entomology 22:519-531.

DeBach, P. and D. Rosen. 1990. Biological control by natural enemies. Cambridge University Press, Cambridge; New York.

Delisle, J. M. and J. A. Savidge. 1997. Avian use and vegetation characteristics of conservation reserve program fields. Journal of Wildlife Management 61:318-325.

Digweed, S. C., C. R. Currie, H. A. Carcamo, and J. R. Spence. 1995. Digging out the "digging-in effect" of pitfall traps: Influences depletion and disturbance on catches of ground beetles (Coleoptera: Carabidae). Pedobiologia 39:561-576.

Ewald, J. A. and N. J. Aebischer. 1998. Avian food, birds, and pesticides. Report to English Nature FIN/8.10B/97-8. The Game Conservancy Trust, Fordingbridge, Hampshire.

Flickinger, E. L. and G. W. Pendleton. 1994. Bird use of agricultural fields under reduced and conventional tillage in the Texas panhandle. Wildlife Society Bulletin 22:34-42.

Freemark, K. and C. Boutin. 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes - a review with special reference to North-America. Agriculture Ecosystems & Environment 52:67-91.

Freemark, K., H. Dewar, and J. Saltman. 1991. A literature review of bird use of farmland habitats in the Great Lakes-St. Lawrence Region. Can. Wildl. Serv. Tech. Rep.,

Freemark, K. E. and D. A. Kirk. 2001. Birds on organic and conventional farms in Ontario: partitioning effects of habitat and practices on species composition and abundance. Biological Conservation 101:337-350.

French, B. W., N. C. Elliott, S. D. Kindler, and D. C. Arnold. 2001. Seasonal occurrence of aphids and natural enemies in wheat and associated crops. Southwestern Entomologist 26:49-61.

Gaines, J. C. 1957. Cotton insects and their control in the United States. Annual Review of Entomology 2:319-338.

Gaylor, M. J., S. J. Fleischer, D. P. Muehleisen, and J. V. Edelson. 1984. Insect populations in cotton produced under conservation tillage. Journal of Soil and Water Conservation 39:61-64.

Gaylor, M. J. and M. A. Foster. 1987. Cotton pest management in the southeastern United States as influenced by conservation tillage practices. *in* G. J. House and R. E. Stinner, editors. Arthropods in Conservation Tillage Systems. Entomological Society of America, College Park.

Graber, R. R. and J. W. Graber. 1963. A comparative study of bird populations in Illinois, 1906-1909 and 1956-1958. Illinois Natural History Survey 28, Article 3:383-528.

Greenslade, P. J. M. 1973. Sampling ants with pitfall traps - digging-in effects. Insectes Sociaux 20:343-353.

Hill, D. S. and J. D. Hill. 1994. Agricultural entomology. Timber Press, Portland.

Hodler, T. W. and H. A. Schretter. 1986. The Atlas of Georgia. The Institute of Community and Area Development, University of Georgia, Athens.

Hoffman, M. L., M. D. K. Owen, and D. D. Buhler. 1998. Effects of crop and weed management on density and vertical distribution of weed seeds in soil. Agronomy Journal 90:793-799.

Honek, A. 1997. The effect of plant cover and weather on the activity density of ground surface arthropods in a fallow field. Biological Agriculture & Horticulture 15:203-210.

House, G. J. and J. N. All. 1981. Carabid beetles in soybean agroecosystems. Environmental Entomology 10:194-196.

House, G. J. and B. R. Stinner. 1983. Arthropods in no-tillage soybean agroecosystems - community composition and ecosystem interactions. Environmental Management 7:23-28.

Kaspari, M. and A. Joern. 1993. Prey choice by 3 insectivorous grassland birds - reevaluating opportunism. Oikos 68:414-430.

Kershner, E. L. and E. K. Bollinger. 1996. Reproductive success of grassland birds at east-central Illinois airports. American Midland Naturalist 136:358-366.

Kirk, D. A. 1996. Past and current attempts to evaluate the role of birds as predators of insect pests in temperate agriculture. Pages 359 *in* V. Nolan and E. D. Ketterson, editors. Current Ornithology. Plenum Press, New York.

Landis, D. A., S. D. Wratten, and G. M. Gurr. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology 45:175-201.

Lanyon, W. E. 1995. Eastern Meadowlark. The Birds of North America 160:23 p.

Laub, C. A. and J. M. Luna. 1991. Influence of winter cover crop suppression practices on seasonal abundance of armyworm (Lepidoptera, Noctuidae), cover crop regrowth, and yield in no-till corn. Environmental Entomology 20:749-754.

Laub, C. A. and J. M. Luna. 1992. Winter cover crop suppression practices and natural enemies of armyworm (Lepidoptera, Noctuidae) in no-till corn. Environmental Entomology 21:41-49.

Letourneau, D. K. and B. Goldstein. 2001. Pest damage and arthropod community structure in organic vs. conventional tomato production in California. Journal of Applied Ecology 38:557-570.

Little, V. A. and D. F. Martin. 1942. Cotton insects of the United States. Burgess, Minneapolis.

Lokemoen, J. T. and J. A. Beiser. 1997. Bird use and nesting in conventional, minimum-tillage, and organic cropland. Journal of Wildlife Management 61:644-655.

Luttrell, R. G. 1994. Cotton pest-management: part 2. a US perspective. Annual Review of Entomology 39:527-542.

Maher, W. J. 1979. Nestling diets of prairie passerine birds at Matador, Saskatchewan, Canada. Ibis 121:437-452.

Matthews, G. A. 1989. Cotton insects and their management. Longman Scientific and Technical, New York.

Mayse, M. A. and P. W. Price. 1978. Seasonal development of soybean arthropod communities in east central Illinois. Agro-Ecosystems 4:387-405.

Mirarchi, R. E. and T. S. Baskett. 1994. Mourning Dove. The Birds of North America No. 117:30 p.

National Agricultural Statistics Service, U. S. D. o. A. National Agricultural Statistics Service Homepage. October 2001. Viewed on 15 October 2001. http://www.usda.gov/nass/.

O'Connor, R. J. and M. Shrubb. 1986. Farming and birds. Cambridge University Press, Cambridge.

Palmer, W. 1995. Effects of modern pesticides and farming systems on Northern Bobwhite Quail brood ecology. Ph.D. dissertation, North Carolina State University, Raleigh.

Parajulee, M. N., R. Montandon, and J. E. Slosser. 1997. Relay intercropping to enhance abundance of insect predators of cotton aphid (*Aphis gossypii* Glover) in Texas cotton. International Journal of Pest Management 43:227-232.

Parajulee, M. N. and J. E. Slosser. 1999. Evaluation of potential relay strip crops for predator enhancement in Texas cotton. International Journal of Pest Management 45:275-286.

Partners In Flight. Species Assessment Database. 2001. 14 January 2002. Viewed on 1 March 2002. http://www.rmbo.org/pif/pifdb.html.

Phatak, S. C. 1992. An integrated sustainable vegetable production system. Hortscience 27:738-741.

Phatak, S. C. 1993. Legume cover crops-cotton relay cropping system. Pages 280-285 *in* C. I. f. R. Studies, editor. Organic Cotton Conference: An Edited Collection of Farm Profiles, Scholarly Papers, Articles, Facts, Statistics and Clippings on Sustainable Cotton Production.

Phatak, S. C. 1998. Managing pests with cover crops. Pages 25-33 *in* Managing Cover Crops Profitably. Sustainable Agriculture Network, Beltsville, MD.

Phatak, S. C., R. Reed, W. Fussell, W. J. Lewis, and G. H. Harris. 1999. Crimson clover-cotton relay cropping with conservation tillage system. Pages 184-188 *in* J. E. Hook, editor. Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Georgia Agricultural Experiment Stations, The University of Georgia, Tifton, Georgia.

Potts, D. 1997. Cereal farming, pesticides and grey partridges. Pages 150-177 *in* D. J. Pain and M. W. Pienkowski, editors. Farming and Birds in Europe. Academic Press, San Diego.

Rasmussen, W. D. 1982. The mechanization of agriculture. Scientific American 247:76-89.

Rodenhouse, N. L. and L. B. Best. 1983. Breeding ecology of vesper sparrows in corn and soybean fields. American Midland Naturalist 110:265-275.

Rodenhouse, N. L. and L. B. Best. 1994. Foraging patterns of vesper sparrows (*Pooecetes gramineus*) breeding in cropland. American Midland Naturalist 131:196-206.

Rodenhouse, N. L., L. B. Best, R. J. O'Connor, and E. K. Bollinger. 1993. Effects of temperate agriculture on Neotropical migrant landbirds. Pages 280-295 *in* D. M. Finch and T. Stangel, editors. Status and Management of Neotropical Migratory Birds. USDA Forest Serv. Rocky Mt. Forest Range Exp. Sta.,

Rodenhouse, N. L., L. B. Best, R. J. O'Connor, and E. K. Bollinger. 1995. Effects of agricultural practices and farmland structures. Pages 269-293 *in* T. E. Martin and D. M. Finch, editors. Ecology and Management of Neotropical Migratory Birds: A Synthesis and Review of Critical Issues. Oxford University Press, New York.

Roland, J., S. J. Hannon, and M. A. Smith. 1986. Foraging pattern of Pine Siskins and its influence on winter moth survival in an apple orchard. Oecologia 69:47-52.

Sahoo, U. K., R. S. Tripathi, and H. N. Pandey. 1995. Dynamics of buried seed population of weeds as influenced by conventional tillage and no-tillage in Meghalaya. Indian Journal of Agricultural Sciences 65:49-53.

SAS Institute, I. 1990. SAS procedure guide, version 6, 3rd ed. SAS Institute, Inc., Cary.

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, results and analysis 1966-2000. Version 2001.2. USGS Patuxent Wildlife Research Center, Laurel, MD.

Sauer, J. R., B. G. Peterjohn, S. Schwartz, and J. E. Hines. 1995. The grassland bird home page. Version 95.0. Patuxent Wildlife Research Center, Laurel, MD.

Scheaffer, R. L., W. Mendenhall III, and R. L. Ott. 1996. Elementary survey sampling. Duxbury Press,

Shelton, M. D. and C. R. Edwards. 1983. Effects of weeds on the diversity and abundance of insects in soybeans. Environmental Entomology 12:296-298.

Sherry, T. W. and R. T. Holmes. 1995. Summer versus winter limitation of populations: conceptual issues and evidence. Pages 85-120 *in* T. Martin and D. Finch, editors. Ecology and Management of Neotropical migratory birds: a synthesis and review of the critical issues. Oxford University Press, New York.

Smith, M. W., D. C. Arnold, R. D. Eikenbary, N. R. Rice, A. Shiferaw, B. S. Cheary, and B. L. Carroll. 1996. Influence of ground cover on beneficial arthropods in pecan. Biological Control 6:164-176.

Smith, T. F., J. L. Apple, and D. G. Bottrell. 1976. The origins of integrated pest management concepts for agricultural crops. Pages 1-16 *in* J. Apple and R. Smith, editors. Integrated Pest Management. Plenum Press, New York.

Sotherton, N. W. 1995. Beetle banks- helping nature to control pests. Pesticide Outlook 6:13-17.

Sotherton, N. W. 1998. Land use changes and the decline of farmland wildlife: an appraisal of the set-aside approach. Biological Conservation 83:259-268.

Sotherton, N. W. and S. J. Moreby. 1992. The importance of beneficial arthropods other than natural enemies in cereal fields. Aspects of Applied Biology 31:11-18.

Stallman, H. R. and L. B. Best. 1996. Use of an experimental strip intercropping system in northeast Iowa. Journal of Wildlife Management 60:354-362.

Stern, V., R. F. Smith, R. van den Bosch, and K. S. Hagen. 1959. The integrated control concept. Hilgardia 29:81-101.

Stinner, B. R. and G. J. House. 1990. Arthropods and other invertebrates in conservation-tillage agriculture. Annual Review of Entomology 35:299-318.

Stoddard, H. L. 1931. The Bobwhite Quail: its habits, preservation, and increase. Charles Scribner's Sons, New York.

Sundaramurthy, V. T. and R. T. Gahukar. 1998. Integrated management of cotton insect pests in India. Outlook On Agriculture 27:261-269.

Theunissen, J. 1994. Effects of intercropping on pest populations in vegetable crops. IOBC/WPRS Bulletin 17:153-158.

Thomas, L., J. L. Laake, J. F. Derry, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. Strindberg, S. L. Hedley, M. L. Burt, F. F. C. Marques, J. H. Pollard, and R. M. Fewster. 1998. Distance 3.5. Version Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. Available: http://www.ruwpa.st-and.ac.uk/distance/.

Toscano, N. C., V. Sevacherian, and R. A. Van Steenwyk. 1979. Pest management guide for insects and nematodes of cotton in California. Division of Agricultural Sciences, University of California, Berkeley.

Tremblay, A., P. Mineau, and R. K. Stewart. 2001. Effects of bird predation on some pest insect populations in corn. Agriculture Ecosystems & Environment 83:143-152.

Uri, N. D. 2000. Global climate change and the effect of conservation practices in US agriculture. Environmental Geology 40:41-52.

van Emden, H. F. 1965. The effect of uncultivated land on the distribution of cabbage aphid (*Brevicoryne Brassicae*) on an adjacent crop. Journal of Applied Ecology 2:171-196.

van Emden, H. F. 1989. Pest control. Edward Arnold, London.

Vickery, P. D. 1996. Grasshopper Sparrow. The Birds of North America 239:23 p.

Warburton, D. B. and W. D. Klimstra. 1984. Wildlife use of no-till and conventionally tilled corn fields. Journal of Soil and Water Conservation 39:327-330.

White, F. C. and M. E. Wetzstein. 1995. Market effects of cotton integrated pest-management. American Journal of Agricultural Economics 77:602-612.

Wiens, J. A. and J. T. Rotenberry. 1979. Diet niche relationships among North American grassland and shrubsteppe birds. Oecologia 42:253-292.

Woronecki, P. P. and R. A. Dolbeer. 1980. The influence of insects in bird damage control. Pages 53-59 *in* J. P. Clark, editor. Proceedings of the Vertebrate Pest Conference, University of California, Davis.

Yancy, C. 1994. Covers Challenge Cotton Chemicals. The New Farm 16:20-23.

Yenish, J. P., J. D. Doll, and D. D. Buhler. 1992. Effects of tillage on vertical-distribution and viability of weed seed in soil. Weed Science 40:429-433.

APPENDICES

Appendix A. Species detected on transects in cotton fields in central Georgia, 1999-2000, grouped by behavior into three general guilds; sparrow, scrub, and ground.

| **SPARROW GUILD** | | |
|---|---|---|
| **Species** | | **Season**[1] |
| Chipping Sparrow | *Spizella passerina* | B |
| Dark-eyed Junco | *Junco hyemalis* | W |
| Field Sparrow | *Spizella pusilla* | B |
| Grasshopper Sparrow | *Ammodramus savannarum* | B |
| Savannah Sparrow | *Passerculus sandwichensis* | W |
| Song Sparrow | *Melospiza melodia* | W |
| Vesper Sparrow | *Pooecetes gramineus* | W |
| White-crowned Sparrow | *Zonotrichia leucophrys* | W |
| White-Throated Sparrow | *Zonotrichia albicollis* | W |
| Unknown Sparrow | | |

| **SCRUB GUILD** | | |
|---|---|---|
| **Species** | | **Season** |
| Bobolink | *Dolichonyx oryzivorus* | M |
| Brewers Blackbird | *Euphagus cyanocephalus* | W |
| Common Grackle | *Quiscalus quiscula* | B |
| Dicksissel | *Spiza americana* | M |
| Eastern Kingbird | *Tyrannus tyrannus* | S |
| Great-crested Flycatcher | *Myiarchus crinitus* | S |
| Indigo Bunting | *Passerina cyanea* | S |
| Orchard Oriole | *Icterus spurius* | S |
| Painted Bunting | *Passerina ciris* | S |
| Red-winged Blackbird | *Agelaius phoeniceus* | B |
| Summer Tanager | *Piranga rubra* | S |
| Yellow breasted Chat | *Icteria virens* | S |

| **GROUND GUILD** | | |
|---|---|---|
| **Species** | | **Season** |
| Common Ground Dove | *Columbina passerina* | B |
| Eastern Meadowlark | *Sturnella magna* | B |
| Horned Lark | *Eremophila alpestris* | B |
| Killdeer | *Charadrius vociferus* | B |
| Mourning Dove | *Zenaida macroura* | B |
| Northern Bobwhite Quail | *Colinus virginianus* | B |

[1] The time of the year the species is found in Georgia; W: winter, M: migration, S: summer (breeding), B: winter and summer

Appendix B. Species richness and Shannon-Wiener Diversity index for avian transect data for cotton fields in central Georgia during 1999 and 2000 (plot pooled).

| | | | 1999 | | | 2000 | | |
|---|---|---|---|---|---|---|---|---|
| | **Common Name** | ***Genus Species*** | **Conventional** | **Clover** | **Conservation** | **Conventional** | **Clover** | **Conservation** |
| | American Crow | *Corvus brachyrhynchos* | 4 | 2 | 3 | 15 | 4 | 2 |
| ↓§ | American Kestrel | *Falco sparverius* | | | | 1 | | |
| § | American Pipit | *Anthus rubescens* | | | | | 77 | |
| | American Robin | *Turdus migratorius* | | | | | | 17 |
| | Barn Swallow | *Hirundo rustica* | 5 | 30 | 20 | 6 | 30 | 17 |
| | Blue Grosbeak | *Guiraca caerulea* | 7 | 25 | 38 | 5 | 48 | 45 |
| ↓ | Blue Jay | *Cyanocitta cristata* | 1 | | 2 | | 2 | |
| | Bobolink | *Dolichonyx oryzivorus* | | | | | 295 | 100 |
| | Brewers Blackbird | *Euphagus cyanocephalus* | | | | | 1 | |
| Я | Brown Thrasher | *Toxostoma rufum* | | 3 | | | 2 | 2 |
| | Brown-headed Cowbird | *Molothrus ater* | | 1 | 12 | 21 | 9 | 17 |
| | Cattle Egret | *Bubulcus ibis* | 1 | 52 | 73 | 32 | 275 | 6 |
| | Chimney Swift | *Chaetura pelagica* | | 55 | 66 | | 5 | 2 |
| | Chipping Sparrow | *Spizella passerina* | | | | 1 | 55 | 18 |
| | Common Grackle | *Quiscalus quiscula* | | 9 | 11 | 11 | 20 | 15 |
| Я | Common Ground Dove | *Columbina passerina* | | 6 | 2 | 3 | 5 | 3 |
| | Common Yellow-throat | *Geothlypis trichas* | | | 1 | | | |
| | Dark-eyed Junco | *Junco hyemalis* | | | | 10 | | 2 |
| § | Dicksissel | *Spiza americana* | | | | | 4 | |
| | Eastern Bluebird | *Sialia sialis* | 1 | 4 | | 8 | 7 | 19 |
| | Eastern Kingbird | *Tyrannus tyrannus* | 1 | 31 | 57 | 25 | 30 | 31 |
| ↓§ | Eastern Meadowlark | *Sturnella magna* | | 13 | 5 | 1 | 108 | 13 |
| | Eastern Phoebe | *Sayornis phoebe* | | | 1 | | 1 | |

Appendix B. Continued

| | Common Name | Genus Species | 1999 | | | 2000 | | |
|---|---|---|---|---|---|---|---|---|
| | | | Conventional | Clover | Conservation | Conventional | Clover | Conservation |
| § | Eastern Towhee | *Pipilo erythrophthalmus* | 1 | | | | | 2 |
| ↓Я | Field Sparrow | *Spizella pusilla* | | 3 | 4 | 1 | 2 | 12 |
| | Fish Crow | *Corvus ossifragus* | | | 1 | | 6 | |
| § | Grasshopper Sparrow | *Ammodramus savannarum* | | 12 | 9 | | 2 | |
| | Great Blue Heron | *Ardea herodias* | | 1 | | | | |
| | Great-crested Flycatcher | *Myiarchus crinitus* | 1 | | | | 1 | |
| | Horned Lark | *Eremophila alpestris* | 21 | 114 | 32 | 3 | 3 | 75 |
| | Indigo Bunting | *Passerina cyanea* | 9 | 1 | 13 | 1 | 14 | 9 |
| Я | Killdeer | *Charadrius vociferus* | | 39 | 9 | 6 | 22 | 4 |
| ↓Я | Loggerhead Shrike | *Lanius ludovicianus* | | 5 | 1 | | 1 | |
| | Mourning Dove | *Zenaida macroura* | 107 | 145 | 181 | 31 | 88 | 27 |
| ↓Я | Northern Bobwhite Quail | *Colinus virginianus* | | 7 | 1 | | 12 | 32 |
| | Northern Cardinal | *Cardinalis cardinalis* | 7 | 3 | 13 | 19 | 8 | 15 |
| § | Northern Harrier | *Circus cyaneus* | | | 1 | 1 | 1 | |
| | Northern Mockingbird | *Mimus polyglottos* | | 5 | 18 | 1 | 15 | 11 |
| | Orchard Oriole | *Icterus spurius* | | 6 | 5 | 1 | 19 | 1 |
| | Painted Bunting | *Passerina ciris* | 1 | | 2 | | 1 | 1 |
| § | Palm Warbler | *Dendroica palmarum* | | | | | | 5 |
| Я | Prairie Warbler | *Dendroica discolor* | | | | | | 1 |
| | Purple Martin | *Progne subis* | 5 | 15 | 4 | | | 1 |
| | Red tailed Hawk | *Buteo jamaicensis* | | | 1 | | | |
| ↓ | Red-winged Blackbird | *Agelaius phoeniceus* | 13 | 152 | 110 | 2 | 478 | 169 |
| | Rock Dove | *Columba livia* | | | | | | 1 |
| | Ruby-throated Hummingbird | *Archilochus colubris* | 1 | | | | 1 | |
| | Savannah Sparrow | *Passerculus sandwichensis* | | 82 | 13 | 44 | 341 | 235 |

Appendix B. Continued

| Common Name | *Genus Species* | 1999 Conventional | 1999 Clover | 1999 Conservation | 2000 Conventional | 2000 Clover | 2000 Conservation |
|---|---|---|---|---|---|---|---|
| Song Sparrow | *Melospiza melodia* | | | | 11 | 66 | 112 |
| Summer Tanager | *Piranga rubra* | | | | | 1 | 1 |
| Tree Swallow | *Tachycineta bicolor* | | | 3 | 1 | 25 | 8 |
| Vesper Sparrow | *Pooecetes gramineus* | | | | 16 | 16 | 14 |
| White-crowned Sparrow | *Zonotrichia leucophrys* | | | | | 2 | |
| White-Throated Sparrow | *Zonotrichia albicollis* | | | | | 2 | |
| Wild Turkey | *Meleagris gallopavo* | | 3 | 1 | | 9 | |
| Yellow breasted Chat | *Icteria virens* | | 1 | | | 1 | |
| Yellow-Rumped Warbler | *Dendroica coronata* | | | | | 8 | 7 |
| | **Total # of Species** | **17** | **29** | **33** | **27** | **46** | **38** |
| | **Total # of Individuals** | **186** | **825** | **713** | **277** | **2123** | **1052** |
| | **Shannon-Weiner Index** | **2.37** | **3.67** | **3.66** | **3.95** | **3.69** | **3.89** |

↓ Significant population decline (>50% since 1966 according to Breeding Bird Survey).
я Typically of conservation concern throughout range (Partners In Flight 2001).
§ Moderate overall priority, yet are of concern in the Southeastern Coastal Plain Bird Conservation Region (Partners In Flight 2001).

Appendix C. List of Orders and Families of insects collected in pitfall traps during 1999 and 2000 in central Georgia, with the corresponding variables for arthropod length/width regression models from Palmer (1995).

| Order | Family | Common Name | LL[1] | LW | Constant | Type[2] |
|---|---|---|---|---|---|---|
| Arachnida | (Class) | Spider | -1.5 | -2 | 8.27 | B |
| Chilopoda | (Class) | Centipedes | -1.37 | -1.71 | 8.19 | B |
| Coleoptera | | Beetle | -1.58 | -1.5 | 8.61 | |
| Coleoptera | | larva | -1.37 | -1.71 | 8.19 | |
| Coleoptera | Anthicidae | Antlike flower beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Bostrichidae | Branch-and-twig borer | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Carabidae | Ground beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Cebrionidae | Cebrionid beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Chrysomelidae | Leaf beetle | -1.58 | -1.5 | 8.61 | P |
| Coleoptera | Chrysomelidae SF Alticinae | Flea beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Cicindelidae | Tiger beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Cleridae | Checkered beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Coccinellidae | Lady beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Cryptophagidae | Silken fungus beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Cucujidae | Flat bark beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Curculionidae | Snout beetle/weevil | -1.58 | -1.5 | 8.61 | P |
| Coleoptera | Elateridae | Click beetle | -1.58 | -1.5 | 8.61 | P |
| Coleoptera | Histeridae | Hister beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Mordellidae | Tumbling Flower Beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Nitidulidae | Sap beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Rhizophagidae | Rhizophagid beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Scarabaeidae | Scarab beetle | -1.58 | -1.5 | 8.61 | P |
| Coleoptera | Scolytidae | | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Scolytidae SF Ipinae | Bark-and-ambrosia beetles | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Silphidae | Carrion beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Staphylinidae | Rove beetle | -1.58 | -1.5 | 8.61 | B |
| Coleoptera | Tenebrionidae | Darkling beetle | -1.58 | -1.5 | 8.61 | P |
| Coleoptera | Trogositidae | Bark-gnawing beetles | -1.58 | -1.5 | 8.61 | B |
| Coleptera | Mycetophagidae | Hairy Fungus Beetles | -1.58 | -1.5 | 8.61 | B |
| Dermaptera | Forficulidae | Common earwig | -1.97 | -1.34 | 9.2 | B |
| Dermaptera | Labiduridae | Long-horned earwigs | -1.97 | -1.34 | 9.2 | B |
| Dermaptera | Labiidae | | -1.97 | -1.34 | 9.2 | B |
| Diplopoda | (Class) | Millipede | -1.37 | -1.71 | 8.19 | B |
| Diptera | | Fly | -4.25 | | 12.44 | B |
| Diptera | Bombyliidae | Bee flies | -4.25 | | 12.44 | B |
| Diptera | Muscidae | Muscid fly | -4.25 | | 12.44 | B |
| Diptera | Suborder Nematocera | Midges, mosquitoes, gnats | -4.25 | | 12.44 | B |
| Diptera | Tabanidae | Deer fly | -4.25 | | 12.44 | B |
| Hemiptera | | | -1.32 | -1.28 | 8.22 | |
| Hemiptera | | immature | -1.32 | -1.28 | 8.22 | |
| Hemiptera | Alydidae | Broad-headed bugs | -1.32 | -1.28 | 8.22 | B |
| Hemiptera | Cimicidae | Bedbug | -1.32 | -1.28 | 8.22 | B |
| Hemiptera | Cydriidae | Burrower bug | -1.32 | -1.28 | 8.22 | B |

Appendix C. continued.

| Order | Family | Common Name | LL | LW | Constant | Type |
|---|---|---|---|---|---|---|
| Hemiptera | Dipsocoridae | Jumping ground bugs | -1.32 | -1.28 | 8.22 | B |
| Hemiptera | Lygaeidae | Seed bug | -1.32 | -1.28 | 8.22 | B |
| Hemiptera | Miridae | Plant bugs | -1.32 | -1.28 | 8.22 | P |
| Hemiptera | Nabidae | Damsel bug | -1.32 | -1.28 | 8.22 | B |
| Hemiptera | Reduviidae | Assassin bugs | -1.32 | -1.28 | 8.22 | B |
| Hemiptera | Schizopteridae | Ground jumping bugs | -1.32 | -1.28 | 8.22 | B |
| Homoptera | | | -2.05 | -2.02 | 9.64 | P |
| Homoptera | Aphidae | Aphids | -6.02 | | 12.95 | P |
| Homoptera | Cicadellidae | Leafhoppers | -1.35 | -2.54 | 8.97 | P |
| Hymenoptera | | | -3.49 | | 11.31 | B |
| Hymenoptera | | Wasp (Large) | -3.49 | | 11.31 | B |
| Hymenoptera | | Wasp (Small) | -3.49 | | 11.31 | B |
| Hymenoptera | Andrenidae | Andrenid bees | -3.49 | | 11.31 | B |
| Hymenoptera | Apidae | Bees | -3.49 | | 11.31 | B |
| Hymenoptera | Apidae SF Anthophorinae | Digger and Cuckoo bees | -3.49 | | 11.31 | B |
| Hymenoptera | Apidae SF Apinae | Honey bee | -3.49 | | 11.31 | B |
| Hymenoptera | Apidae SF Xylocopinae | Large carpenter bees | -3.49 | | 11.31 | B |
| Hymenoptera | Superfamily Apoidea | Bees | -3.49 | | 11.31 | B |
| Hymenoptera | Argidae | Argid sawfly | -3.49 | | 11.31 | B |
| Hymenoptera | Superfamily Chalcidoidea | Chalcids | -3.49 | | 11.31 | B |
| Hymenoptera | Eupelmidae | Eupelmids | -3.49 | | 11.31 | B |
| Hymenoptera | Formicinae | Ant | -3.49 | | 11.31 | B |
| Hymenoptera | Halictidae | Halicitid bees | -3.49 | | 11.31 | B |
| Hymenoptera | Halictidae | Halictid bee | -3.49 | | 11.31 | B |
| Hymenoptera | Megachilidae | Leafcutting bees | -3.49 | | 11.31 | B |
| Hymenoptera | Mutillidae | Velvet ant | -3.49 | | 11.31 | B |
| Hymenoptera | Myrmicinae | Fire ant | -3.49 | | 11.31 | B |
| Hymenoptera | Pompilidae | Spider wasp | -3.49 | | 11.31 | B |
| Hymenoptera | Superfamily Proctotrupoidea | | -3.49 | | 11.31 | B |
| Hymenoptera | Scelionidae | Scelionids | -3.49 | | 11.31 | B |
| Hymenoptera | Sphecidae | Sphecid wasp | -3.49 | | 11.31 | B |
| Hymenoptera | Sphecidae SF Sphecinae | Thread-waisted wasp | -3.49 | | 11.31 | B |
| Hymenoptera | Vespidae | Vespid wasp | -3.49 | | 11.31 | B |
| Isoptera | | Termite | -2.05 | -2.02 | 9.64 | P |
| Lepidoptera | | Butterfly (adult) | -1.37 | -1.71 | 8.19 | B |
| Lepidoptera | | Moth (adult) | -1.37 | -1.71 | 8.19 | P |
| Lepidoptera | | larva | -1.37 | -1.71 | 8.19 | P |
| Lepidoptera | Hesperiidae | Skippers | -1.37 | -1.71 | 8.19 | B |
| Lepidoptera | Noctuidae | Noctuid moths | -1.37 | -1.71 | 8.19 | P |
| Lepidoptera | Nymphalidae | Brush-footed butterflies | -1.37 | -1.71 | 8.19 | B |
| Lepidoptera | Pieridae | Sulfurs | -1.37 | -1.71 | 8.19 | B |
| Neuroptera | | Lacewings, Antlions | -1.97 | -1.34 | 9.2 | B |
| Orthoptera | Acrididae | Short-horned grasshoppers | -0.98 | -1.61 | 7.58 | P |
| Orthoptera | Acrididae SF Acridinae | Slant-faced grasshoppers | -0.98 | -1.61 | 7.58 | P |
| Orthoptera | Acrididae SF Oedipodina | Band-winded grasshopper | -0.98 | -1.61 | 7.58 | P |
| Orthoptera | Gryllidae | Cricket | -1.75 | -1.54 | 8.28 | P |

Appendix C. continued.

| Order | Family | Common Name | LL | LW | Constant | Type |
|---|---|---|---|---|---|---|
| Orthoptera | Gryllidae SF Gryllinae | Field/House cricket | -1.75 | -1.54 | 8.28 | P |
| Orthoptera | Gryllidae SF Gryllotalpinae | Mole cricket | -1.75 | -1.54 | 8.28 | P |
| Orthoptera | Gryllidae SF Oecanthinae | Tree cricket | -1.75 | -1.54 | 8.28 | B |
| Orthoptera | Tetrigidae | Pygmy grasshoppers | -0.98 | -1.61 | 7.58 | B |
| Orthoptera | Tettigoniidae | Long-horned grasshoppers | -1.02 | -1.96 | 6.88 | B |
| Orthoptera | Tridactylidae | Pygmy mole cricket | -1.75 | -1.54 | 8.28 | B |
| Thysanoptera | | Thrips | -2.05 | -2.02 | 9.64 | P |
| Unknown | Larva | | -1.37 | -1.71 | 8.19 | |
| Unknown | Unknown spp. | | -1.97 | -1.34 | 9.2 | |

[1] LL and LW indicate the natural log of length and natural log of width, respectively. The equation to determine arthropod weight (g) is Exp[(LL*LN(length))+(LW*LN(width))-Constant] (Palmer 1995).

[2] B refers to insects which are beneficial or neural, while P are pest insects in cotton fields. Those without a Type listing have both beneficial and pest species and were not used in the BEN/PEST calculations.