VEGETATION RESPONSE IN FIELD MARGINS MANAGED FOR NORTHERN BOBWHITE (*Colinus virginianus*) AND POTENTIAL NEGATIVE IMPACTS OF BERMUDAGRASS (*Cynodon dactylon*)

by

JASON KEITH BURKHART

(Under the Direction of John Carroll)

ABSTRACT

Declining northern bobwhite (*Colinus virginianus*) (bobwhite) populations in Georgia led to the establishment of the Bobwhite Quail Initiative (BQI), a state-funded incentive program aimed at increasing habitat for bobwhites in agricultural landscapes. One of the key management techniques was establishment of linear field margins around row-crop fields using winter disking. I surveyed these field margins for composition of subsequent vegetation and found that invasive and exotic grasses were pervasive. I tested two herbicides, Fusion® and Select 2EC®, to control bermudagrass (*Cynodon dactylon*) within constraints of the program. The single grass-specific herbicide application was ineffective at slowing bermudagrass encroachment. I also tested potential effects of bermudagrass on quail brood habitat and found that it acted as a heat trap by creating areas with temperatures above critical thresholds for bobwhite. The high density of bermudagrass patches was a mechanical barrier to bobwhite chick movement. Both of these findings lend support to anecdotal observations of the negative effects of bermudagrass on bobwhite brood habitat.

INDEX WORDS: Bermudagrass, Bobwhite Quail Initiative, *Colinus virginianus*, Fusion®, Georgia, Habitat management, Heat trap, Grass herbicide, Northern bobwhite, Select 2EC®

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DEDICATION

I dedicate this to my family: Illana, Shelby, Kip, Momma, Daddy, Stacy, Jessica, Mom, and Jonathan. Illana, my beautiful wife, thank you for your never-ending love and patience through all of this. To the rest of my wonderful family, thank you for all of your help, support, thoughts, and prayers over the last several years especially.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

The state of Georgia was once known as the "Quail Capital of the World" due to the abundant population of the Northern Bobwhite (*Colinus virginianus*) (bobwhite). However, bobwhite populations have declined during at least the last 40 years (Brennan 1991). These declining bobwhite population trends have concerned government officials and citizens in Georgia. To address this concern, Georgia's General Assembly worked with the Georgia Department of Natural Resources (GA-DNR) to create and fund the Bobwhite Quail Initiative (BQI), which was implemented during the autumn of 1999. The purpose of this incentive program was to restore quality habitat for bobwhite in farmland ecosystems (GA DNR 1999). The program was based in the Upper Coastal Plain, and by early 2002, a total of 17 counties were included in the program with more than 150 landowners and farmers participating.

The decline of bobwhite populations has largely been the result of loss of early successional habitats, primarily due to changes in farms and farming practices (Brennan 1991). The BQI program goal is to improve early successional habitats in farmland ecosystems in the Upper Coastal Plain of Georgia by using a variety of management tools in field margins, hedgerows, pivot corners, and pine (*Pinus* spp.) stands.

Quality brood-rearing habitat is one of the key components for maintaining bobwhite populations, and so it was necessary to assess whether current BQI management regimes generated quality brood habitat. To determine this, I examined managed areas from two perspectives. First, I measured vegetative response to BQI habitat management to assess habitat quality for bobwhite broods. Because invasive plant species, such as bermudagrass (*Cynodon* *dactylon*), can reduce brood habitat quality, I documented invasion and potential negative impacts of invasive plants on brood ecology to assess the value of BQI habitat management. As a second objective, I explored control options for potential problem plant species, particularly bermudagrass. The overall goal of this research was to ascertain whether brood habitats generated by BQI management are likely to increase recruitment.

BACKGROUND

Northern Bobwhite Biology

Because bobwhites have been hunted widely, they are one of the most extensively and intensely studied bird species in the world (Guthery 1997). Their economic importance is great, especially in the southern and mid-western United States (Brennan 1999, Burger *et al.* 1999). There have been numerous studies of bobwhites that focus on different aspects of the life history and ecology. Stoddard (1931) wrote what is still today one of the most important texts on bobwhite behavior, ecology, and management. Leopold (1933) covered aspects of bobwhite management in his book *Game Management*, and Roseberry and Klimstra (1984) wrote about bobwhite population ecology in the Midwest. Guthery (2000) wrote about the life, management, populations, and issues facing bobwhites and bobwhite management today.

Populations of bobwhite can be found throughout eastern North America, west to the Great Plains, north to New England and southern Canada, and south to Mexico. They are sedentary, year-round residents (Stoddard 1931). In the East, where forested habitats are more dominant, bobwhites utilize early successional habitats associated with agricultural fields and grasslands, relatively open-canopy pine, and mixed pine-hardwood forests.

Adult bobwhites feed primarily on seeds and succulent parts of green plants. Chicks, however, are almost completely insectivorous during the first 6-8 weeks of their life (Stoddard

1931), presumably because of the increased protein levels necessary for growth and development.

Bobwhites have small home ranges and often low dispersal rates. Bobwhites can move quickly along the ground when disturbed, and some disturbances result in the explosive take-off so familiar to quail hunters. Flights are very short, lasting only a few seconds, and cover less than a few hundred meters (Brennan 1999).

In the Southeast, the breeding season lasts from April to September. Females may renest several times and produce more than one brood in a season. Both sexes can select the nest site and will often build the nest together (Rosene 1969). Nests are built on the ground, typically near openings and are at least partially covered by standing vegetation. Eggs, incubated by either or both adults, hatch in about 23 days. Chicks are precocial, but must be brooded until full thermoregulatory control is achieved at about 30 days after hatching (Borchelt and Ringer 1973). Chicks take their first flight at about 14 days and are fully grown in 15 weeks.

In warm climates, such as occurs in the Southeast, this delay in thermoregulatory ability suggests that there may be potential effects of hot weather and hyperthermia on chick survival. Anecdotal observations of bobwhite chick mortality due to high temperatures have been recorded. Guthery (2000) found critical temperatures of 26.7-29.4 C at which bobwhites begin to dissipate heat. Heat dissipation is no longer effective at 39 C, and prolonged exposure to temperatures at or above 40 C is lethal. Normal body temperature for a bobwhite is 42.6 C, and body temperatures of 46.7-47.2 C are lethal to most vertebrates, including bobwhites. The darker coloration of bobwhites may make them even more vulnerable to hyperthermia due to absorption of solar radiation (Guthery *et al.* 2000).

Anecdotal observations by biologists have suggested the presence of sod forming grasses in monocultures may act as a heat trap. Grasses such as, bermudagrass, may hold heat at ground level, thereby creating a thermally challenging environment for bobwhites. In addition, competition by sod forming grasses may inhibit taller forbs from growing. This taller vegetation with open structure underneath creates shaded zones, which may be substantially cooler. In previous studies, Guthery *et al.* (2000) found that bobwhites utilized cooler habitats than those randomly available in subtropical environments.

Although brood habitat has been extensively studied, the importance of bobwhite chick mobility has not been investigated. Bobwhites must be able to move easily on the ground to obtain food and avoid predators (Lehmann 1946, Murphy and Basket 1952). However, there have been no quantitative studies of how inhibition of chick mobility in different environments might impact survival. The linear field borders established by the BQI are at high risk for invasion by highly aggressive and invasive sod forming grasses from adjacent habitats (see Chapter 2). Understanding how chick mobility is inhibited may allow us to understand mechanisms impacting brood survival.

Bobwhite Quail Initiative Management

The BQI program provides monetary incentives and technical assistance to private land managers to increase early successional habitat in row crop agriculture systems. Qualification and enrollment in the program is based on a minimum score derived from the habitat that can be provided. Those that enroll must maintain the minimum score throughout the duration of their three-year enrollment. Inspections are made twice each year: planting and after harvest.

When large fields were broken up by fencerows and unfarmed weedy areas they provided soft edges (transition zones) where the habitat changed gradually. Native vegetation grew with only periodic disturbance from a plow or controlled fire. Those practices contributed to the boom in bobwhite populations. The once small fields separated by areas of grasses, shrubs, and small trees have now been combined to form expansive fields maintained by mechanized farming practices. Technological advances in machinery, as well as advances in chemical control of pests, allowed crops to be planted up to the less favorable bobwhite habitats. This intensive farming allows few, if any, soft edges between the mechanically maintained crop field and the surrounding habitat types (such as forests). Currently, most field borders are hard edges where the forest edge stands in stark contrast to the crop field. These hard edges provide little habitat value to bobwhites.

Within the BQI program it was decided that increasing early successional habitat on enrolled farms had to have minimal impact on farming operations. Wherever possible, biologists attempt to re-establish brushy fencerows and hedgerows. Ten-meter-wide linear habitats (field borders) are established at the perimeter of the existing fields or through the interior of fields to break up large areas. Unfarmed areas, particularly pivot corners, are left fallow to provide block habitat patches. During the first winter of enrollment, the enrolled areas are lightly disked. Then these areas are left undisturbed and allowed to grow in natural vegetation over a 3-year contract.

Previous field conditions will affect the composition of vegetation in managed areas of the BQI. Many of the crop fields entered in the program are old pastures and some are agricultural areas that have existed for decades. Many enrolled crop fields have herbaceous or grass borders. It is unknown how the existing seed bank will change the overall vegetative composition. Knowing the makeup and change of vegetation within BQI over time will make management decisions within the program more effective.

Bermudagrass Ecology

Although it is uncertain when bermudagrass was first introduced into the United States from southeast Africa, it most likely occurred during the mid-1800s (Harlan 1970). By the mid-1900's bermudagrass could be found throughout the southeastern United States and ranged as far as California, Michigan and Massachusetts (Hitchcock and Chase 1950). Bermudagrass is a warm-season, mat-forming, prostrate perennial grass that is used for erosion control, turfgrass, livestock feed, and recreational areas. Although it reproduces by seeds, it spreads most rapidly by rhizomes and stolons to form a resilient turf. Bermudagrass will grow on most soils, but it grows best on fertile, sandy to silty soils, or alluvium. The grass begins growth late in the spring, continues through the heat of summer and becomes dormant in the fall. It is considered an early-successional species, and shade can slow or even eliminate it. Bermudagrass is also susceptible to cold temperatures.

Bermudagrass is an aggressive, invasive species in ornamentals, turfgrass, and commercial crops (Gilliam *et al.* 1984; Hicks and Jordan 1984; Johnson and Talbert 1989; and McCarty 1996). In these situations the grass spreads quickly forming near monocultures and out-competing other species. Although potentially important relative to nesting and brood habitat, researchers have not investigated the effects of bermudagrass control on bobwhite.

OBJECTIVES

The two main objectives of my research were:

1) Determine plant species composition of BQI managed field borders for two years following treatment. Within this objective, I assessed the presence and extent of invasive species in BQI managed field borders as well as successional changes.
2) Determine effects of bermudagrass invasion on northern bobwhite brood habitat quality and assess grass control options. Within this objective, I explored economical control options of invasive plant species, determined effects of bermudagrass on chick mobility, and determined effects of bermudagrass as a heat trap.

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CHAPTER 2

VEGETATION COMPOSITION OF BOBWHITE QUAIL INITIATIVE FIELD MARGINS

INTRODUCTION

The orderly and predictable change in plant communities over time is termed plant succession. In the Southeast, the first year after soil disturbance, plants such as ragweed (*Ambrosia artimisiifolia*), sicklepod (*Senna obtusifolia*), and *Dichanthelium* spp. are often seen. In subsequent years, perennials that persist for two or more growing seasons become prevalent. Over a time of two to three years, perennial plant populations succeed annual populations.

Mechanical soil disturbance to promote plant growth beneficial to wildlife is a common method of habitat management. Light disking, or harrowing, can be very beneficial to bobwhites in the southeastern United States if applied during late autumn and winter. Germination and growth of plants, such as ragweed and partridge pea (*Chamaecrista* spp.), utilized for cover (e.g. for protection from predators or high temperatures) and foraging is often enhanced by this method. Species found after the first year of growth beneficial to nesting, such as broomsedge (*Andropogon* spp.), can also benefit from winter disking.

As part of the Bobwhite Quail Initiative (BQI), it was important to assess the vegetative response to determine if BQI habitats produced suitable brood habitat. For example, Puckett *et al.* (1995, 2000) found that crop-field margins managed to produce native vegetation, in North Carolina, were used more during summer than unmanaged field margins by bobwhites. Hanson and Labinsky (1964) found pheasants (*Phasianus colchicus)* to be disproportionately associated with crop fields in summer. This indicates the importance of knowing the suitability of adjacent habitats. Therefore, in this study, I compared vegetation composition and structure in BQI managed fields and non-BQI fields, quantified abundance of beneficial plant species in BQI fields, and surveyed for invasive plant species in BQI managed field borders.

STUDY AREA

This study was conducted in the Upper Coastal Plain of Georgia. Row crop agricultural fields were selected in Bulloch, Burke, Dougherty, Dodge, Jenkins, and Laurens counties. The fields represented 23 landowners and included the Central, East, and Southwest regions of the BQI. The typical row crop field was intensively managed for commercial crop production, particularly cotton. Chemical (herbicide and insecticide) and mechanical (harrowing or plowing) crop management are used to control insects and non-crop plants. Crops typically were planted to the edges of fields, leaving no transition zone to adjacent habitats, other fields, or wooded areas. See Hamrick (2002) for detailed description of the study areas.

METHODS

Study plots were established in 42 cotton fields; of which 22 were enrolled in the BQI program, and were designated as treatment fields, and 20 non-BQI fields were designated as controls. These control fields provided a comparison of BQI established habitat to standard row crop agricultural practices (e.g. no established field borders). Treatments were conducted during winter of 1999-2000, prior to the 2000 growing season. In each treatment field, 10-m wide strips or field borders were established along the perimeter of the fields. These strips were lightly disked and allowed to grow in natural vegetation without disturbance during the following growing seasons. I established one 10 x 100 m study plot per field in the field border of BQI fields and at the field edge of control fields.

To select the location of the plot, I marked the northeast corner each field on an aerial photograph and then traced the perimeter of the field. A random percentage of the field perimeter was chosen, and this distance was paced off in a clockwise direction from the northeast corner and marked to signify the beginning of the study plot. Along the long edge of each plot, transects were established across the plot at distances of 10, 25, 40, 60, 75, and 90m. Vegetation was surveyed along these transects twice each summer during the summers of 2000 and 2001, at least 30 days apart. Along each transect, four groups of measurements were taken.

I used a line intercept survey by stretching a tape across the plot and recording the presence/absence of vegetative species considered of most interest to bobwhite management at half-meter intervals. A plant was recorded if any part of it touched the vertical plane of the tape within each interval. Only one "hit" was recorded for each plant in each interval. Species were recorded in either specific or general categories that included: bermuda grass (*Cynodon dactylon*), bahaia grass (*Paspalum notatum*), broomsedge, miscellaneous grass, ragweed, blackberry (*Rubus* spp.), beggarweed (*Desmodium spp.*), partridge pea, miscellaneous forb, miscellaneous legume, woody, litter, and bare ground. For analysis, the number of occurrences of a species was summed for each study plot by category.

At 2.5, 5.0, and 7.5m along each transect, I estimated percentage overhead cover. A 1-m^2 quadrat was centered on the tape at each distance along the transect. While looking down from above, the percent coverage of the quadrat was estimated in each of five categories: grass, forb, woody, bare, and litter. Percentages were recorded in multiples of 10. This measurement gives an indication of ground cover composition. For analysis mean percentages per category per plot were calculated.

Within each 1-m^2 quadrat, a measure of stem density was taken. In each corner of the larger quadrat, a 10cm^2 sub-quadrat measured the suitability of habitat for bobwhite chick movement and foraging. Within each sub-quadrat, vegetation was trimmed using shears to just above ground level. Stems were then counted and classified by species or general category as above. The 4 sub-quadrats provided a mean stem density for the larger quadrat.

I measured canopy height with a Robel pole (Robel *et al*. 1970) at 2.5, 5.0, and 7.5 m along each transect. The Robel pole was read from kneeling height at a distance of 4m from each of the cardinal directions. The pole was marked in half-decimeter increments, and the highest mark that was totally obstructed was recorded. The four readings were averaged for each location along each transect, and for analysis mean canopy height per plot was calculated.

Species occurrence, percentage of overhead cover, stem density and canopy height were compared to those in control fields including within-year effects by Analysis of Variance (ANOVA) using SAS® software (SAS Institute 2000). First and second survey results, for the summer of 2000, within treatment for each measurement were analyzed by Repeated Measures ANOVA using SAS®. Vegetation survey results for canopy height between treatments were compared with first year data using a *t*-test in SAS®.

Results from the second year of data collection (summer 2001) were calculated from the portions of the study plots left unsprayed with herbicide (half of each treatment plot was treated with an herbicide for another dimension of the project). Vegetation survey results from line intercept and percentage of overhead cover measurements were each compared by plant type by ANOVA using SAS. Results between surveys for each measurement were analyzed by Repeated Measures ANOVA using SAS®. Vegetation survey results for canopy height among surveys were compared with second year data by Repeated Measures ANOVA using SAS®.

RESULTS

Line-intercept

During the first year following treatment, I found greater frequency of occurrence of vegetation in BQI-treated fields than in control fields ($F_{1,360} = 37.07$, $P < 0.0001$). Greater frequencies of occurrence of bermudagrass, miscellaneous grass, and ragweed were found in BQI-treated fields (Tukey HSD, $P < 0.05$). In addition, vegetation type ($F_{8,360} = 399.0$, $P < 0.0001$), and treatment-vegetation type interactions were significant ($F_{8,360} = 35.89$, $P < 0.0001$; Table 2.1).

I found no difference in vegetation occurrence among surveys in BQI treatment fields ($F_{1,168} = 0.02$, $P = 0.89$), nor did I observe a time-vegetation type effect ($F_{8,168} = 1.64$, $P = 0.12$). However, vegetation types ($F_{8,168} = 224.66$, $P < 0.0001$) detected between surveys were different (Table 2.1). I did find a difference among surveys for vegetation occurrence in control fields ($F_{1,152} = 20.08$, $P < 0.0001$), and I found a survey-vegetation interaction effect ($F_{8,152} = 21.51$, $P < 0.0001$). In addition, vegetation types ($F_{8,152} = 297.20$, $P < 0.0001$) detected between surveys were different (Table 2.1).

Second year data in BQI treatment fields shows a difference in overall vegetation occurrence between surveys ($F_{1,360} = 12.95$, $P = 0.0004$), and time-vegetation type interaction ($F_{8,360} = 5.45$, P < 0.0001). An increase in the presence of broomsedge, miscellaneous grasses and ragweed was seen between survey times (Tukey HSD, $P < 0.05$). In addition, vegetation types detected between surveys were different ($F_{8,360} = 148.14$, $P < 0.0001$; Table 2.2).

Percent Overhead Coverage

I found no difference in overall overhead coverage between BQI-treated fields and controls ($F_{1,120} = 0.06$, $P = 0.81$). However, there was a higher percentage of the grass vegetation type in BQI-managed fields, and control fields had a higher percentage of bare ground ($F_{2,120} = 75.25$, $P < 0.0001$). Treatment-vegetation type interactions ($F_{2,120} = 21.69$, $P < 0.0001$) were different (Figure 2.1).

BQI treatment fields were not different between surveys ($F_{1,42} = 0.05$, $P = 0.83$), however, they did show a difference in vegetation type between surveys ($F_{2,42} = 7.03$, $P = 0.002$). In addition, differences between bare ground and grass vegetation types ($F_{2,42} = 18.46$, $P <$ 0.0001) were significant (Figure 2.1). Control fields were not different in overall overhead coverage between surveys ($F_{1,38} = 0.08$, $P = 0.78$), however, they were different in vegetation composition between surveys ($F_{2,38} = 74.36$, $P < 0.0001$). In addition, bare ground and forb vegetation types ($F_{2,38} = 404.84$, $P < 0.0001$) were different (Figure 2.1).

Second year results in BQI treatment fields were different between surveys ($F_{1,90} = 25.36$, $P <0.0001$) and time-vegetation type interaction effects ($F_{2,90} = 35.61$, $P <0.0001$). However, vegetation types were not different ($F_{2,90} = 2.47$, $P = 0.09$) (Figure 2.2).

Canopy Height

I found no difference in canopy height between BQI-treated fields and control fields ($t_{40} = 0.24$, $P = 0.81$). I found no difference among surveys in BQI-treatment fields ($F_{1,21} = 2.35$, $P =$ 0.14). I found no difference among surveys in canopy height in control fields ($F_{1,19} = 0.83$, $P =$ 0.37) (Figure 2.3). For second year BQI treatment fields, I found a difference in canopy height between surveys ($F_{1,45} = 26.42$, $P <0.0001$) (survey 1 mean = 0.82, SE = 0.24; survey 2 mean = 2.29, SE = 0.45).

DISCUSSION

Vegetation in BQI-managed fields and the control fields differed early in the growing season. The control fields chosen were planted in the traditional row crop fashion and lacked established field borders, usually an unplanted strip. The BQI-managed areas began the season as bare soil after their winter disking. Without separate borders in the control fields, the planted crop quickly became the dominant and only vegetation type present, whereas the BQI areas promoted the growth of many different vegetation types.

Many control fields were either unplanted or recently planted at the time of the first survey, so little to no vegetation was shown to be present. By the second survey, the agricultural crop dominated as the single type of vegetation. These differences in vegetation type and quantity are to be expected when an area is allowed to grow in native vegetation as opposed to an area that is highly controlled by mechanical or chemical means.

The percentage of overhead cover was similar for BQI treatment fields and control fields. This was attributed to the crop canopy in control fields. As the crop grew in the control fields, it provided desirable overhead protection from sun and predators. The important differences were seen in the change of vegetation types over time. The treatment fields remained approximately the same, whereas the control fields changed to reflect crop growth. Thus treatment fields developed potentially beneficial overhead canopy and insect producing vegetation earlier than field margins planted to a crop. This may have provided earlier nesting cover as well as protection for broods produced in the breeding season. Both of these characteristics are important to bobwhite chick survival and recruitment as noted by Stoddard (1931). The presence of overhead cover is also encouraging because it may function similarly to tall shrubs in Oklahoma, that were found to be the preferred bobwhite covey location in a study by Wiseman and Lewis (1981)

No statistical difference in canopy height was seen between the BQI treatment fields and the control fields. This may be a result of growth rates that were roughly the same or a lack of taller growing species in treatment fields. The lack of change in canopy height was probably most surprising. When no change in height over time was shown, it indicated little to no growth. This seems to be counter-intuitive, but it may simply indicate that the height of total visual obstruction did not change. If this be the case, it does not mean that actual height remained the same only the height at which vision was totally obscured remained similar. Possibly a larger sample size would have reconciled this seeming discrepancy. Lack of apparent growth could also have been attributed to the local environmental conditions.

Data from the second growing season shows results that were expected. When treatment areas were left undisturbed, new "natural" areas developed that have become established with annual and perennial vegetation. The presence of species, such as bermudagrass, thought to be poor for bobwhite habitat was discouraging. However, this discouragement was balanced by the growth of vegetation types, particularly the broad category of forbs, which began to be observed in greater numbers.

MANAGEMENT IMPLICATIONS

This study demonstrated that beneficial plants for quail management, such as ragweed, were present, but others, such as beggarweed and partridge pea, were not typically present in our sample. Warner (1979) found that pheasants were often associated with non-cropland adjacent to crop fields. Bobwhites demonstrate similar behaviors (Puckett *et al*. 1995, 2000). Therefore, new management techniques, such as planting of desirable species, may be incorporated into BQI to make these linear strips more suitable for bobwhites. Broomsedge, an important nesting substrate, was not recorded. However, it often takes several years after disturbance for its presence to be recorded. Ragweed was present, and it is important for providing escape cover from predators, foraging, and solar heating. Invasive plants, such as bermudagrass, were found even in the first year. Leaving strips that were winter disked around the perimeter of crop fields was only marginally effective at promoting bobwhite habitat and may have worsened a previous problem with exotic and invasive grasses. It is important to develop a strategy to manage such species in the early stages of their invasion when they are easier to control.

Management plans can be tailored to effect changes in specific fields or across broad regions based on the species present during this project. By promoting desirable species, like beggarweed, partridge pea, ragweed, and *Rubus* spp., and taking steps to eradicate the undesirable species, such as bermuda and crab grass, the bobwhite habitat once so abundant can again be present in the Upper Coastal Plain of Georgia.

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Table 2.1. Mean occurrence (± 95% CI) by vegetation type in BQI treated (winter disked 10m field margins around annual crop fields, n=22) and non-BQI (control) (n=20) fields during their first year of growth after winter disking. Surveyed fields were in the Upper Coastal Plain of Georgia.

	Survey 1 (May-June 2000)		Survey 2 (July-August 2000)	
Vegetation Type	BQI	Non-BQI	BQI	non-BQI
Bermudagrass	9.73 (31.49)	1.35 (10.93)	10.64 (32.26)	2.85 (24.07)
Bare Ground	116.91 (20.05)	120.00 (0.00)	115.18 (33.81)	119.65 (3.08)
Broomsedge	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Beggarweed	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Misc. Forb	80.18 (63.05)	18.95 (67.97)	73.27 (59.29)	80.90 (55.44)
Misc. Grass	87.23 (58.97)	19.55 (74.93)	94.95 (53.19)	17.05 (25.85)
Partridge Pea	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Ragweed	3.73 (18.24)	0.45 (3.16)	6.27 (28.20)	0.00 (0.00)
Rubus	1.59 (14.62)	0.00 (0.00)	0.32 (2.92)	0.00 (0.00)

Table 2.2. Mean occurrence (+ 95% CI) by vegetation type in BQI treated (winter disked 10m field margins around annual crop fields, n=46) fields during their second year of growth after winter disking. Surveyed fields were in the Upper Coastal Plain of Georgia.

	Survey 1 (May-June 2001)	Survey 2 (June-July 2001)
Bermudagrass	12.26 (26.24)	12.52 (25.77)
Bare Ground	39.89 (41.39)	44.02 (34.59)
Broomsedge	0.00 (0.00)	0.02 (0.29)
Beggarweed	0.00 (0.00)	0.00 (0.00)
Misc. Forb	48.48 (24.83)	46.57 (26.89)
Misc. Grass	9.32 (22.07)	18.61 (33.53)
Partridge Pea	0.13 (0.12)	0.57 (3.94)
Ragweed	5.00 (24.44)	7.78 (26.40)
Rubus	0.61 (4.51)	1.00 (8.66)

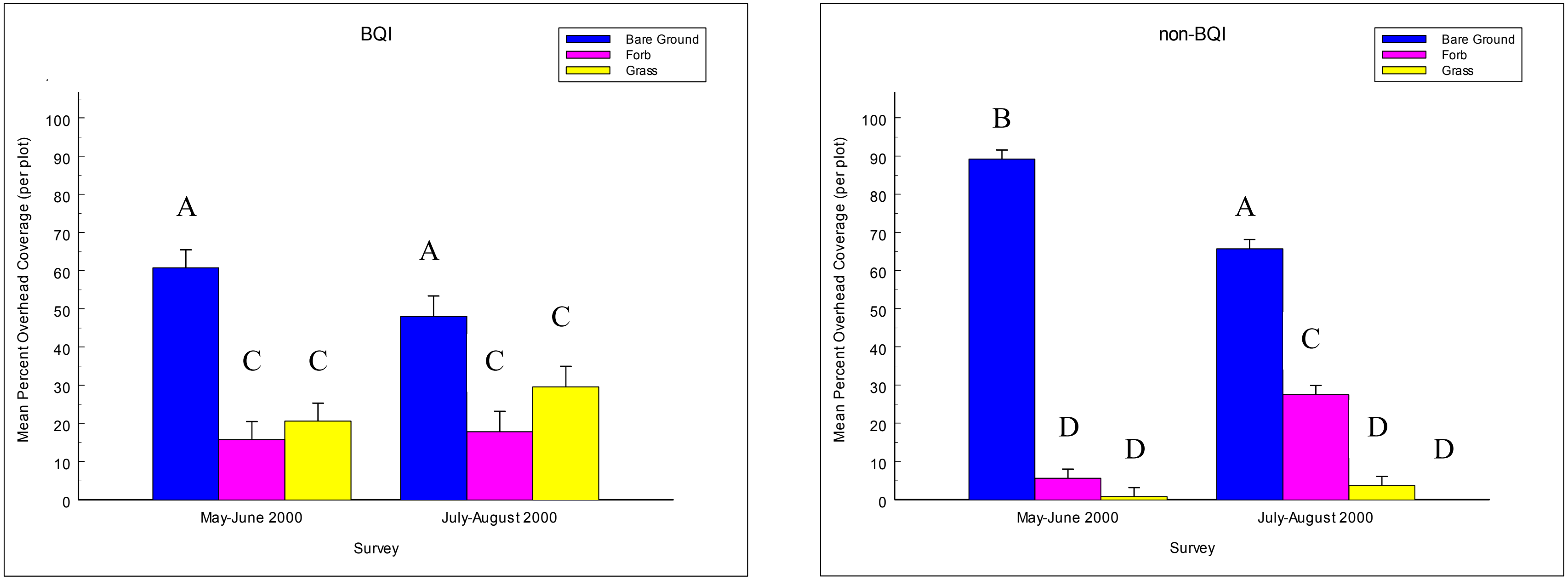

Figure 2.1. Mean percent overhead coverage (±SE) by category in BQI and non-BQI managed fields, with 10m field margins, for early (n=22) and late (n=22) surveys in their first growing season after winter disking. Fields were surveyed during 2000 and were found in the Upper Coastal Plain of Georgia. Bars with same letter are not different (Tukey's HSD, $P < 0.05$).

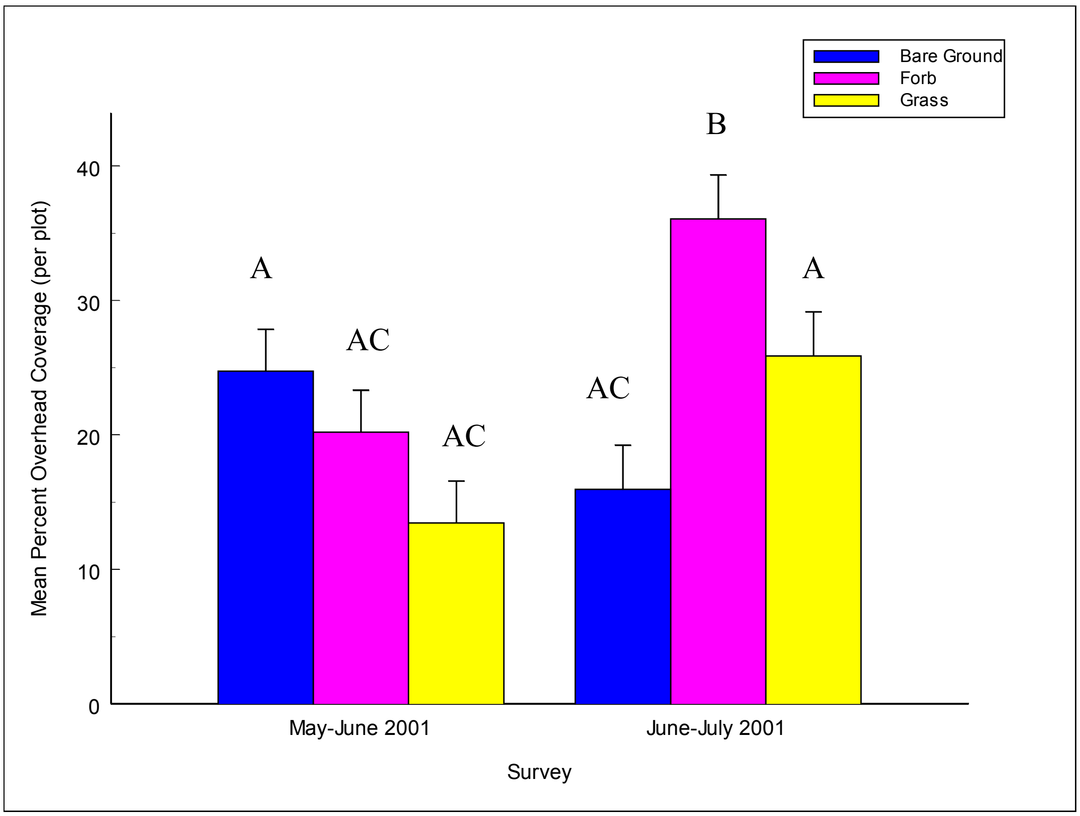

Figure 2.2. Mean overhead percent coverage (+SE) by category for BQI managed fields with 10m field margins for early (n=46) and late (n=46) for second growing season after winter disking. Surveyed fields were found in the Upper Coastal Plain of Georgia. Bars with same letter are not different (Tukey's HSD, $P < 0.05$).

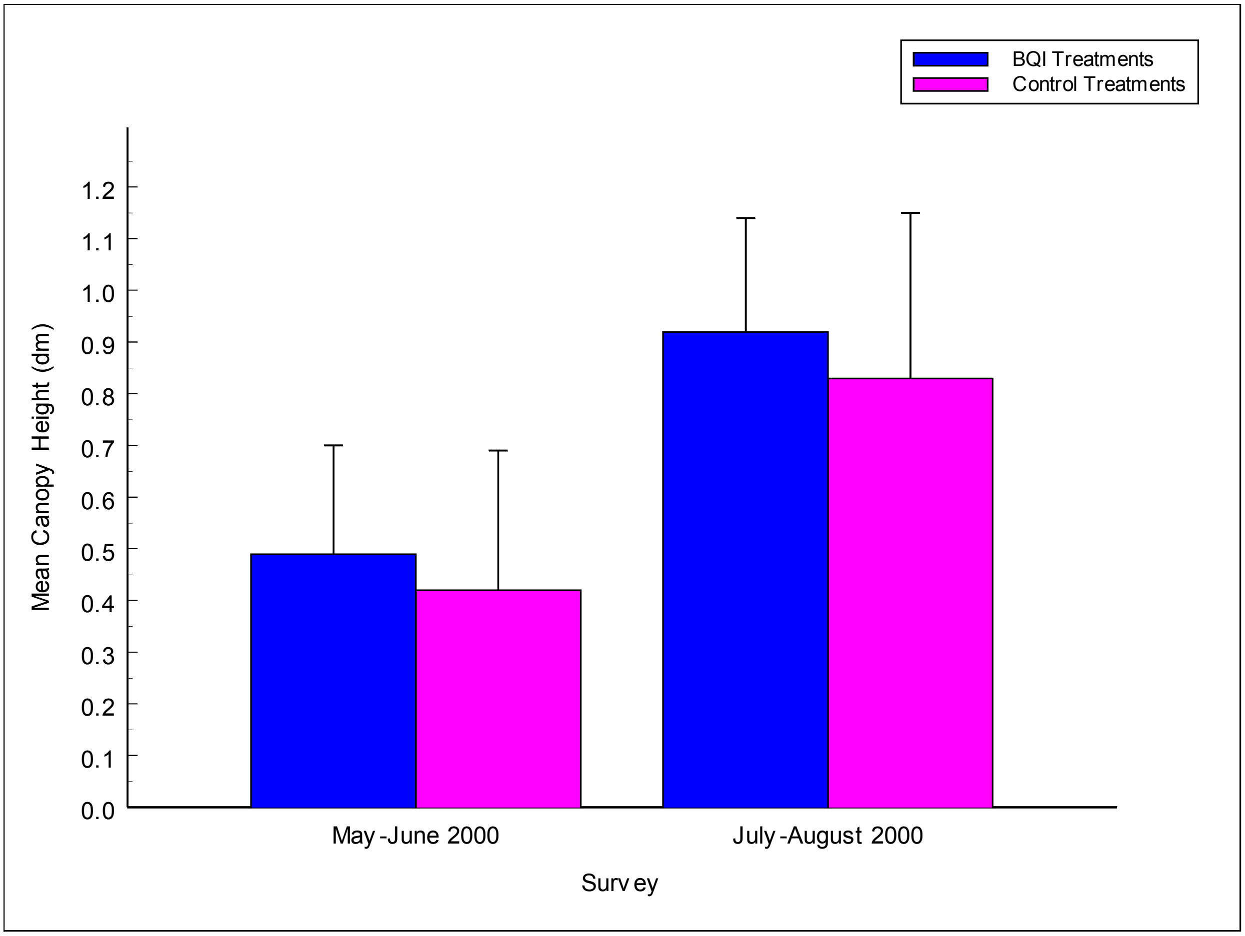

Figure 2.3. Mean canopy height in dm (± SE) in BQI treated fields with 10m field margins (n=22) in their first growing season after disking and control treated fields (n=20) in their first growing season after planting for early and late surveys. Surveyed fields were in the Upper Coastal Plain of Georgia.

CHAPTER 3

CONTROL OF BERMUDAGRASS (*Cynodon dactylon*) USING GRASS-SPECIFIC HERBICIDES

INTRODUCTION

The Georgia Bobwhite Quail Initiative (BQI) is a state funded landowner incentive program that establishes linear early-successional habitats at the perimeter of row crop agricultural fields to provide habitat beneficial to the Northern Bobwhite (*Colinus virginianus*) (bobwhite) in the Upper Coastal Plain of Georgia. The linear nature of these field margins makes them susceptible to invasion by pest species (large edge to area ratio) such as bermudagrass (*Cynodon dactlyon*). Bermudagrass is the common name for one of the East African rhizomatuous species of *Cynodon* (Harlan 1970, Burton and Hanna 1985). Although the actual date is uncertain, introduction of bermudagrass into the United States likely occurred in the mid-1800's (Harlan 1970). Bermudagrass could be found, by the mid-1900's, from California to Florida (Hitchcock and Chase 1950). In an agricultural environment, bermudagrass can be an invasive and competitive weed. It is drought tolerant and can spread rapidly because of its extensive system of rhizomes and stolons. Rhizomes are the primary over-wintering structure (Holm *et al.* 1977). Bermudagrass can tolerate a wide range of soils, but it requires warm weather for growth.

Because bermudagrass frequently occurs in BQI field borders (see Chapter 2), development of a cost-effective method of control became necessary. Total eradication of the grass from the field borders would be difficult, because many of the fields were once managed to enhance bermudagrass for grazing or because bermudagrass has been planted extensively in farmed areas for erosion control. These sources provide for continuous invasion into the narrow strips of bobwhite habitat established by BQI management. Therefore, I tested the efficacy of several methods to inhibit bermudagrass long enough for beneficial species to become established and out-compete the bermudagrass.

A number of factors and constraints contribute to making bermudagrass control a difficult proposition. Many of the enrolled fields were in close proximity to homes, farm buildings, highways, and livestock. These characteristics, along with the now frequent burning bans, made burning the bermudagrass impractical. High-intensity disking would negate the growth of any beneficial vegetation, defeating the purpose of the BQI. Mowing would eliminate the vertical structure provided by other more favorable plants that is necessary for effective bobwhite habitat and would benefit bermudagrass. Chemical control seemed the most viable option.

For the chemical control program to be effective it had to have minimal input, minimal preparation, and low cost. The herbicides used needed to be highly selective, not harming more favorable vegetative species, particularly annual broadleaf weeds. It was crucial that there be no impact on the nearby crop or other nearby vegetation, such as trees or pastures. To control cost and minimize mechanical damage to the field margins, control in a single application was desired.

A grass-specific herbicide seemed the most sensible choice. Only the grasses would be targeted and beneficial forbs would be unharmed. I selected two grass-specific herbicides for evaluation: Fusion® (fluazifop p-butyl, fenoxaprop-p-ethyl) (Syngenta, Wilmington, DE) and Select 2EC® (clethodim) (Valent, Walnut Creek, CA).

Previous studies of the efficacy of grass specific herbicides have produced varying results. Gilliam *et al*. (1984) used grass-specific herbicides to control bermudagrass that had invaded woody ornamentals. They achieved 90% control with a single application of sethoxydim or fluazifop-butyl herbicides. Johnson and Carrow (1991) attempted to control bermudagrass encroachment into creeping bentgrass (*Agrostis palustris*) greens using flurprimidol herbicides, and effective control was not observed. McCarty (1996) investigated controlling bermudagrass invasion into St. Augustine grass using ethofumesate with other chemicals. Satisfactory results were obtained only with multiple applications. Johnson and Talbert (1989) investigated the use of grass-specific herbicides to control bermudagrass in Concord grapes (*Vitis labrusca*). They found effective initial control, but rapid regrowth resulted in no difference in bermudagrass infestation.

Both herbicides I chose are systemic herbicides with little to no ground activity. They are readily transported from the point of uptake to the growing meristem. They have the same mechanism of action. Fatty acid or lipid biosynthesis is halted, and at the cellular level, acetyl Co-enzyme A Carboxylase (ACCase) is inhibited (Ware 2000). This inhibition halts the production of lipids, thereby preventing growth and repair of existing cell walls.

The objective of this study was to determine if one application of grass-specific herbicide could be used as a cost-effective method of controlling bermudagrass in 10-m wide field margins established within the BQI program

STUDY AREA

This study was conducted in the Upper Coastal Plain of Georgia. Row crop agricultural fields typical to the area and enrolled in the Bobwhite Quail Initiative were used. The fields were located in Bleckley, Bulloch, Burke, Dodge, Jenkins, and Laurens counties. The fields represented 17 different landowners. The typical row crop field is very large and highly mechanized. Little vegetation besides the planted crop is allowed to grow. Herbicide and insecticide application is done on a regular schedule, and fields are plowed for weed control when there is no crop present. Crops are often planted to the edges of the field leaving no vegetated margins to the adjacent crop field, forest stand, or roadway.

METHODS

I established 46 study blocks in the field margins of 39 annual crop fields under BQI management regimes in the Upper Coastal Plain of Georgia. Each study block was 10m x 100m. The study blocks were split in half to create control and treatment plots. These plots were randomly assigned to treatment and control. Each treatment was sprayed with one of two grass-specific herbicides.

Herbicides were applied during the first week of May 2001. The herbicide applied was chosen by blind draw with 23 plots receiving Fusion® and 23 plots receiving Select 2EC®. Applications were made at the maximum label rate for bermudagrass (Fusion®- 12 oz/acre and Select 2EC®- 8 oz/acre). An independent spray contractor conducted all spraying operations.

For vegetation surveys, 10m transect lines (across the widths of plots) were marked at 10m, 25m, and 40m along the length of the plots. Transects began at the crop and moved toward the field margin. To determine herbicide effectiveness, three vegetation surveys of each block were conducted at 4-week intervals throughout the summer (25 May 2001 – 6 August 2001), beginning two weeks after spray. The earlier established transect lines were used for surveys. Along each survey line, four measures of vegetation were made.

1. I used line intercept to determine the distance a certain species has spread. The line-intercept surveys were conducted at half-meter intervals using a measuring tape stretched along the earlier established transects. Green bermudagrass touching the vertical plane of the tape at each interval was recorded. These data give presence/absence information for the bermudagrass at each interval. The number of times bermudagrass was present was

calculated for each plot in each survey. These data were analyzed using a repeated-measures analysis of variance (hereafter, ANOVA) with three time intervals and three independent variables using Statistical Analysis System (hereafter, SAS) (SAS Institute 2000). The three independent variables were region, herbicide applied, and treatment or control. A ratio of "hits" in survey 1 to "hits" in survey 3 was calculated. This ratio was analyzed using analysis of variance with three independent variables, region, herbicide applied, and treatment or control using SAS (SAS institute 2000).

2. By using percent overhead coverage I are able to determine the composition of the vegetation canopy. It can also be used to give an indication of the amount of sunlight reaching the ground. Percent overhead coverage measurements were taken at 2.5m, 5.0m, and 7.5m along each transect. At these distances, a one-meter square was centered on the ground along the measuring tape. While looking from overhead the percentage of grass covering the square to the nearest multiple of ten was visually estimated. The mean percent coverage for each plot was calculated for each survey. These data give another indication of spread. These percentages were analyzed by repeated-measures ANOVA with three time intervals and three independent variables. The independent variables used were region, herbicide applied, and treatment or control.
3. Calculating the stem density of an area provides a measure of ground level obstruction. Stem density measurements were taken using the one-meter square from the percent coverage readings. At each corner of the one-meter square, a 10cm square was placed and vegetation within the square was trimmed to a height of 1in using shears. The number of bermudagrass stems in each square was recorded. A mean density per 10cm square was calculated for each plot. These data give an indication of the change in

ground level density over time. The densities were also analyzed using repeated-measures ANOVA and the same three time intervals and independent variables.

4. Vertical obstruction was measured by the Robel pole method (Robel *et al*. 1970). The pole was placed at 2.5m, 5.0m, and 7.5m along each transect and read at kneeling height from each of the cardinal directions from a distance of 2.5m. The pole is marked in alternating colors at every half-decimeter up to 15dm starting at ground level. The highest color band that is completely obstructed from view is recorded. A mean obstruction reading was calculated for each plot. The obstruction heights were also analyzed using a repeated measures analysis of variance and the same three time intervals and levels.

RESULTS

Line-intercept

For Fusion herbicide, I found no difference in presence of bermudagrass among surveys dates ($F_{2,41} = 0.37$, $P = 0.69$), and no date-treatment interaction effect ($F_{2,41} = 0.72$, $P = 0.49$). For Select 2EC herbicide, I found no difference in presence of bermudagrass among surveys dates ($F_{2,41} = 2.81$, $P = 0.07$, and no survey date-treatment interaction effect ($F_{2,41} = 0.10$, $P = 0.91$) (Figure 3.1).

The ratio analysis from Survey 1 to Survey 3 revealed no difference between sprayed and unsprayed areas for both Fusion ($F_{1,42} = 0.05$, $P = 0.82$) and Select 2EC ($F_{1,42} = 1.89$, $P = 0.18$) herbicide treatments (Figure 3.2).

Percent coverage

For Fusion herbicide I found that overhead coverage of bermudagrass increased with survey date ($F_{2,41} = 12.64$, $P < 0.0001$), no survey date-treatment interaction effect ($F_{2,41} = 0.09$, P

= 0.91). For Select 2EC herbicide, I found that overhead coverage of bermudagrass increased during subsequent survey dates ($F_{2,41}$ = 23.62, *P* <0.0001), however, I found no survey date-treatment interaction effect ($F_{2,41}$ = 1.21, *P* = 0.31) (Figure 3.3).

Stem density

For Fusion herbicide, I found no difference in stem density among surveys ($F_{2,41}$ = 0.89, *P* = 0.42), and no survey date-treatment interaction effect ($F_{2,41}$ = 0.01, *P* = 0.99). For Select 2EC herbicide, I found no difference in stem density among surveys ($F_{2,41}$ = 2.89, *P* = 0.07), and no survey date-treatment interaction effect ($F_{2,41}$ = 2.39, *P* = 0.10) (Figure 3.4).

Vertical obstruction

For Fusion herbicide, I found an increase in vertical obstruction over survey dates ($F_{2,41}$ = 7.26, *P* = 0.002). However, no survey date-treatment interaction effect ($F_{2,41}$ = 0.03, *P* = 0.97) was found. For Select 2EC herbicide, I found an increase in vertical obstruction over survey dates ($F_{2,41}$ = 13.72, *P* <0.0001), however, no survey date-treatment interaction effect ($F_{2,41}$ = 0.55, *P* = 0.58) was found (Figure 3.5).

DISCUSSION

Similar to the results of Johnson and Carrow (1991), I found that a single grass herbicide treatment was not sufficient to change plant composition away from bermudagrass. I observed no noticeable reduction in the amount of bermudagrass present from the use of either herbicide. The control of bermudagrass with post-emergence herbicide was found to be more difficult than expected, as in similar studies (Gilliam *et al*. 1984). The lack of difference in the ratio analysis between sprayed and unsprayed areas indicates that the herbicides were ineffective in controlling or even slowing bermudagrass with one application. Stem density measurements and overhead coverage data also indicates the ineffectiveness of the herbicides by allowing the continued spread of grasses.

The canopy height measurements show a significant difference over time and a difference in regions over time. The difference in regions may be attributed to the greater number of irrigated fields in the east region as opposed to the central region.

MANAGEMENT IMPLICATIONS

Management of narrow strips around agricultural fields presents many challenges. Within the constraints of the BQI management program, I realized that complete removal would not be cost effective. However, a single treatment with grass specific herbicides was not sufficient to create substantial changes in bermudagrass invasion. It appears that more aggressive and costly bermudagrass control will be required. I suggest multiple spray treatments, treatments in fall, or use of cool season cover crops might improve quality of these strip habitats.

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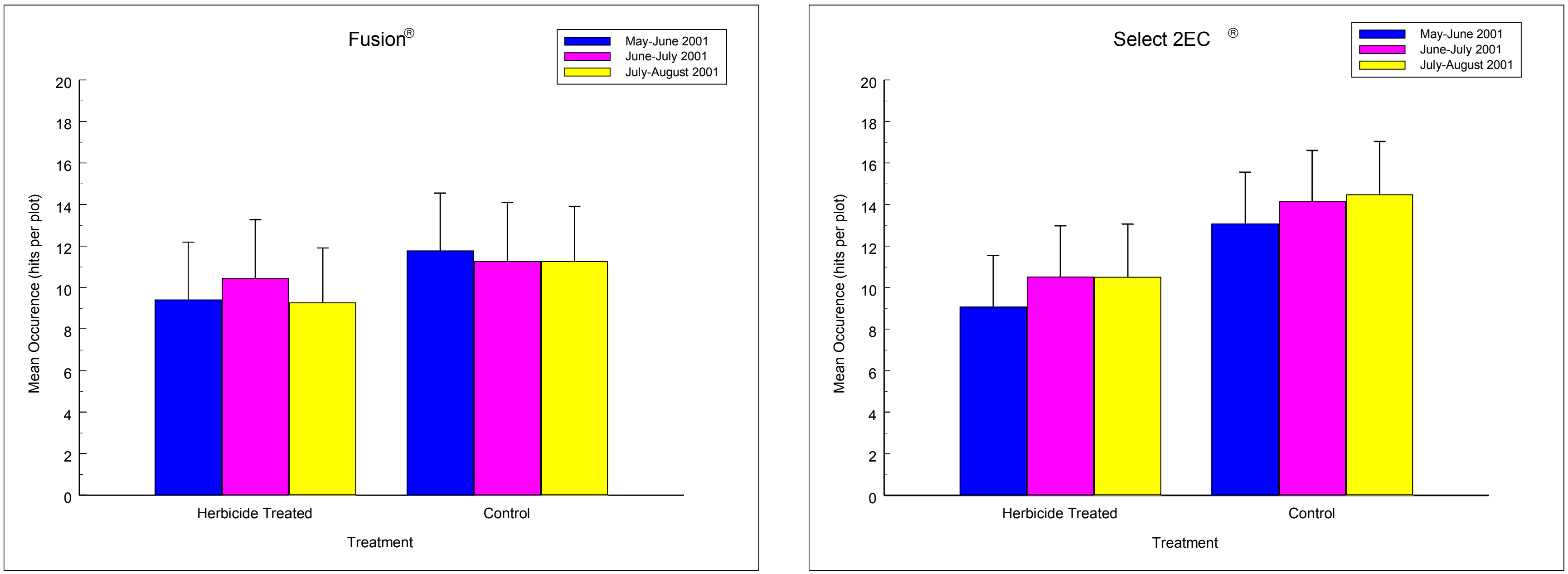


Figure 3.1. Mean occurrence (±SE) of bermudagrass in herbicide treated and control areas of 10 m BQI managed field margins treated with Fusion® and Select 2EC® herbicide in the traditional row crop setting of the Upper Coastal Plain of Georgia. Three surveys were conducted beginning one-month post-treatment.

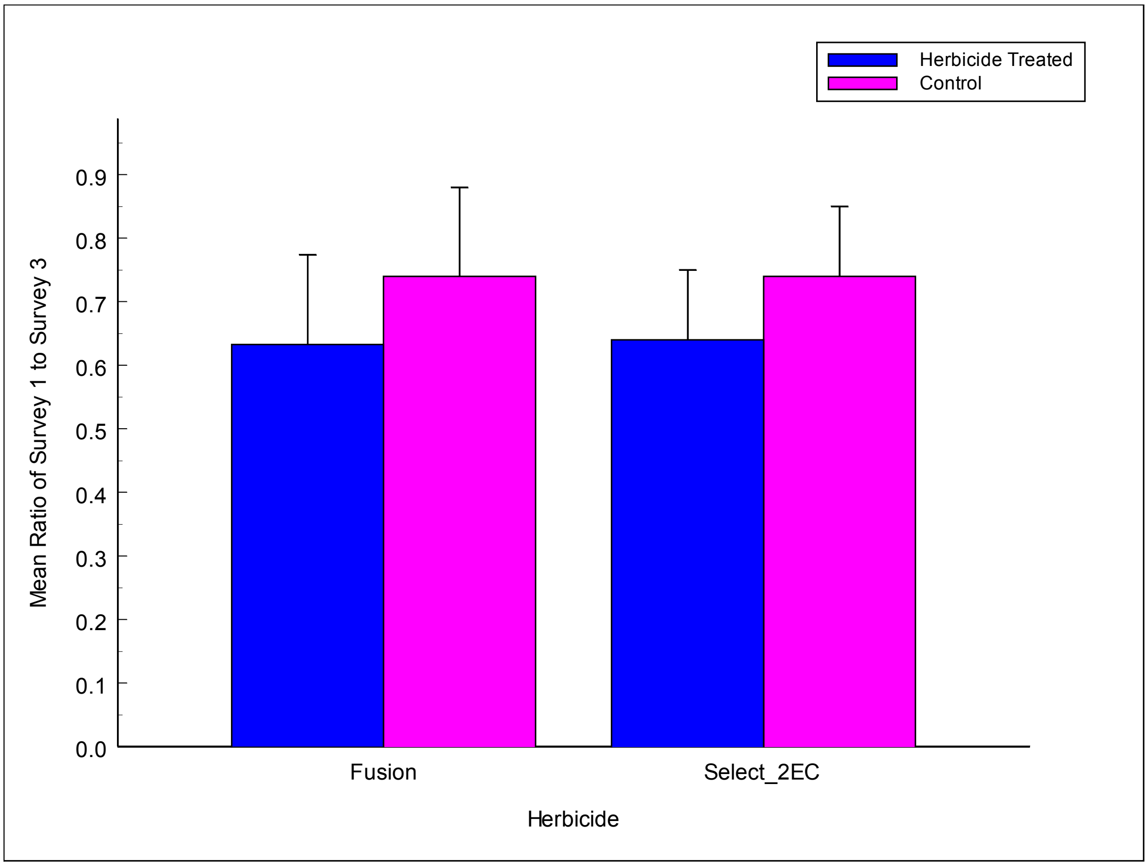
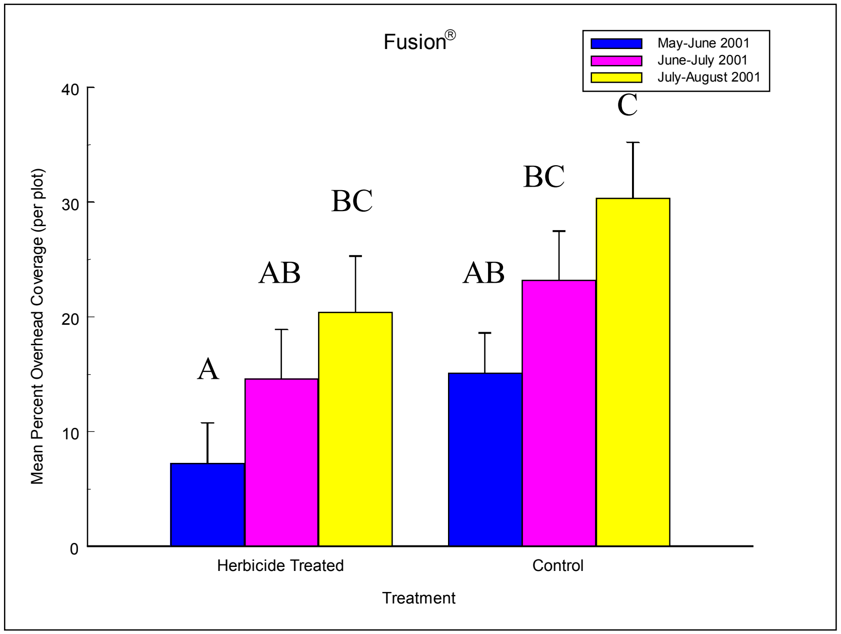


Figure 3.2. Ratio of bermudagrass occurrence (±SE) from survey one to survey three for 10m BQI managed field borders treated with Fusion and Select herbicides in the traditional row crop setting of the Upper Coastal Plain of Georgia.



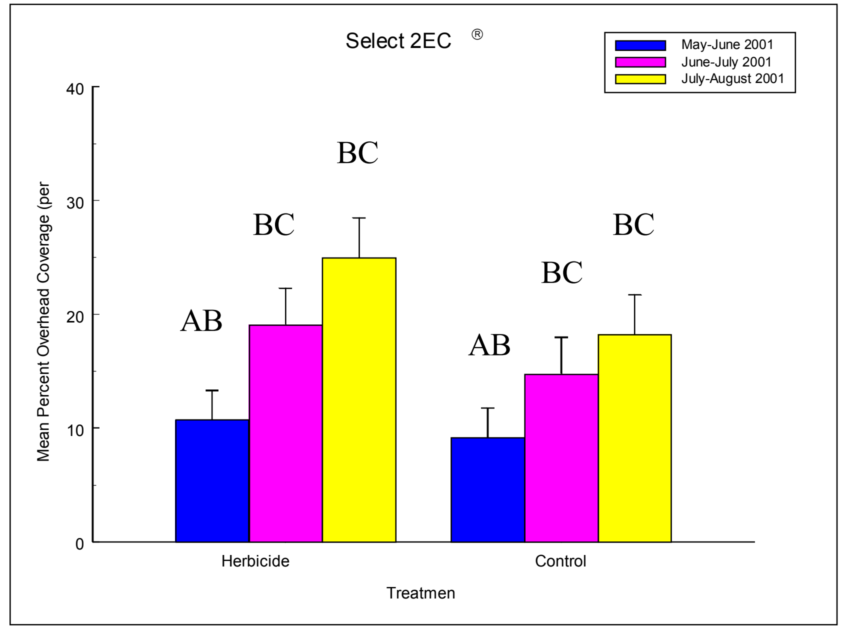


Figure 3.3. Mean percent overhead coverage (±SE) for Fusion® and Select 2EC® herbicide treated and control 10m BQI managed field margins in the traditional row crop setting of the Upper Coastal Plain of Georgia. Bars with same letter are not different (Tukey's HSD, $P < 0.05$).

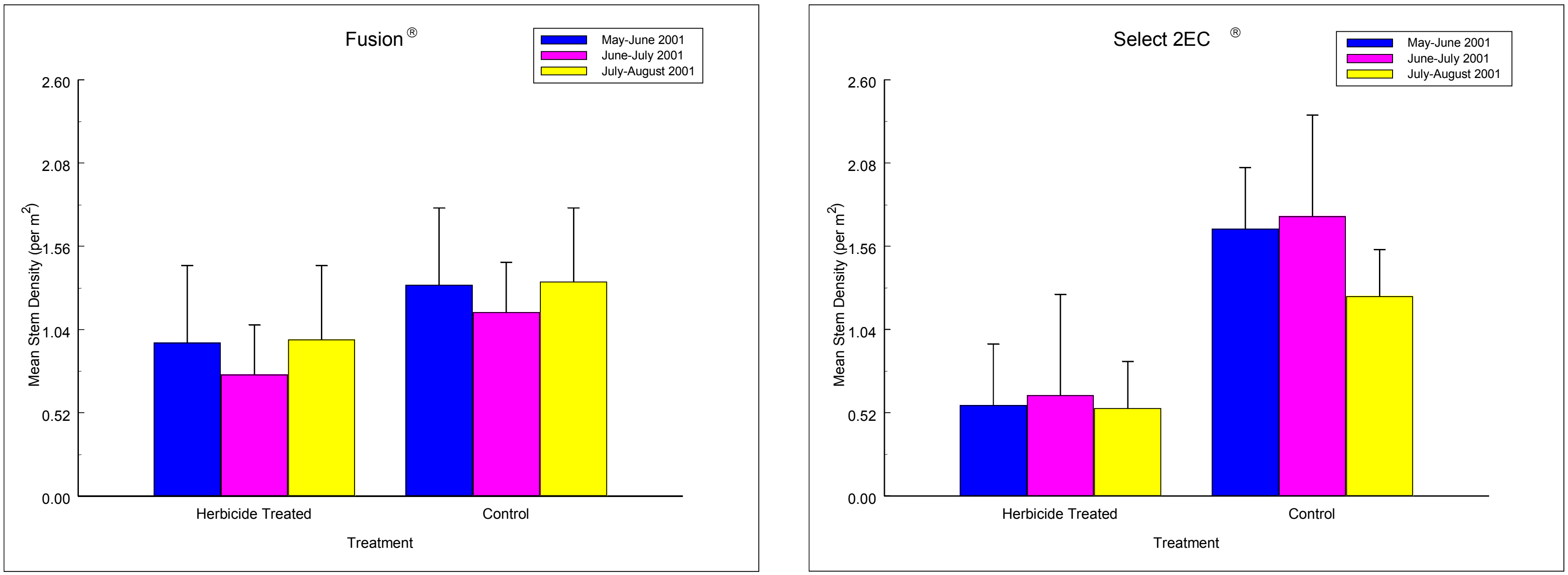


Figure 3.4. Mean stem density (+/- SE) for Fusion® and Select 2EC® herbicide treated and control 10m BQI managed field margins in the traditional row crop setting of the Upper Coastal Plain of Georgia. Bars with same letter are not different (Tukey's HSD, $P < 0.05$).

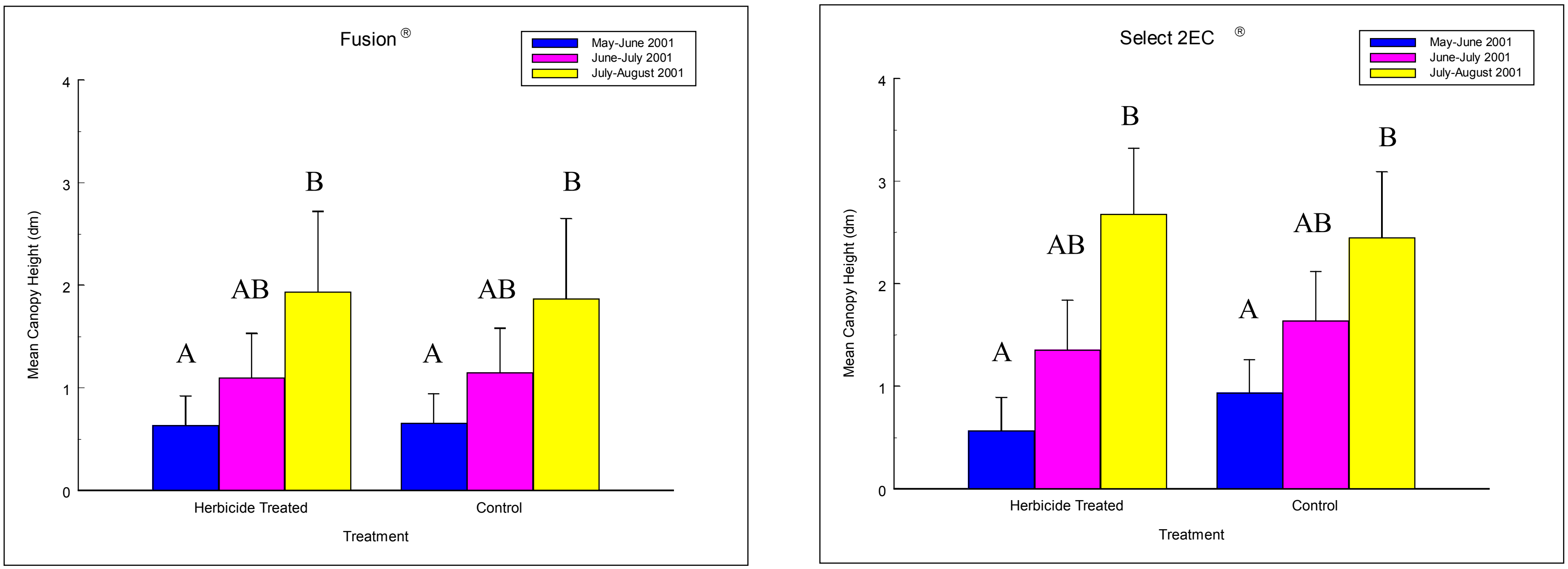


Figure 3.5. Mean vertical obstruction height (dM ±SE) for Fusion® and Select 2EC® herbicide treated and control 10m BQI managed field margins in the traditional row crop setting of the Upper Coastal Plain of Georgia. Bars with same letter are not different (Tukey's HSD, $P < 0.05$).

CHAPTER 4

BERMUDAGRASS (*Cynodon dactylon*) AS A MECHANICAL OBSTRUCTION AND HEAT TRAP FOR NORTHERN BOBWHITE (*Colinus virginianus*) CHICKS

INTRODUCTION

The Bobwhite Quail Initiative (BQI) was implemented in the Upper Coastal Plain of Georgia, in 1999, by the Georgia Department of Natural Resources with funding from the Georgia General Assembly. The BQI establishes linear, early-successional habitat in row crop agricultural areas to increase favorable habitat for the Northern Bobwhite (bobwhite). Annual results from the Breeding Bird Survey show a steady decline in bobwhite populations over the last 30 years in Georgia (Sauer *et al*. 1997). This precipitous decline appears to be a result of the loss of early-successional habitat types (Brennan 1991). These habitats consist of upland sites that are composed of annual grasses and forbs, with overhead coverage for protection and open at ground level for ease of movement. An important concern within the BQI is ensuring that the established habitat is appropriate for brood use. Because chicks are flightless and have shorter, weaker legs, open structure at ground level is critical (deVos and Mueller 1992).
Bermudagrass is a common invasive grass in BQI field borders. It has the ability to spread and form a dense ground layer of cover, excluding native vegetation. This dense ground cover might impact bobwhite chicks by causing higher ground level temperatures that result in thermal stress to chicks and creating mechanical barriers, caused by the dense ground level growth form, which physically impede chick movement.

Much of the published literature on bobwhite brood habitat suggests that ground vegetation should not be so dense that it might inhibit movement and have some bare ground, implying that chick mobility might be impacted (deVos and Mueller 1992). For example, it has been suggested that bobwhites must be able to move freely and easily to obtain food and avoid predators (Lehmann 1946, Murphy and Baskett 1952). However, literature directly addressing the mobility of bobwhite chicks is limited, and no data exist in the published literature to quantify how the mobility of chicks is inhibited in different habitats.

Anecdotal observations of bobwhite chicks dying from simple exposure to heat in typical feeding areas have been made by biologists. At ambient temperatures of 26.7-29.4 C bobwhites begin to dissipate heat (Guthery 2000). Heat dissipation is no longer effective at 39 C, and prolonged exposure to temperatures at or above 40 C is lethal. Normal body temperature for a bobwhite is 42.6 C, and body temperatures of 46.7-47.2 C are lethal to most vertebrates, including bobwhites (Guthery 2000). The darker coloration of bobwhites may make them even more vulnerable to hyperthermia due to absorption of solar radiation (Guthery *et al.* 2000).

Dense bermudagrass may act as a heat trap, due to its growth form and lack of shading. If bermudagrass acts as a heat trap, it is creating a thermally challenging environment. Guthery *et al.* (2000) indicate that bobwhites utilized habitats cooler than those randomly available in the environment, therefore bermudagrass may reduce the quality and quantity of habitat available to broods.

Hill and Robertson (1988) found pheasant (*Phasianus colchicus*) chicks cannot maintain body temperature in their early life, and may require periodic brooding by the hen. Similar to pheasants, bobwhite chicks do not gain full physiological control of thermoregulation until 30 days after hatching (Borchelt and Ringer 1973). During hot summer days, young bobwhites are often brooded in the shade of trees, bushes, or other ground vegetation until clouds pass over and the family group moves out to feed (Stoddard 1931). Bobwhites prefer habitats with operative temperatures <39 C (Forester *et al.* 1998, Guthery *et al.* 2000), and increased mortality of embryos in eggs, chicks, and adults was observed during prolonged temperatures over 39 C (Guthery *et al.* 2001). Bobwhite chicks, particularly at a very young age, must be able to maintain proper thermoregulation, and it is critical that the managed areas provide suitable microclimate.

In this study, I examined two components of bermudagrass in BQI managed field margins for its potential impact on bobwhite brood habitat. First, I investigated if bermudagrass may inhibit the mobility of bobwhite chicks. I hypothesized that high-density bermudagrass would be most inhibitory to movement and zero density will have the least impact on movements. My second objective was to determine if bermudagrass patches had a higher mean daily temperature than areas of annual broadleaf weeds, therefore acting as a heat trap.

STUDY AREA

The study area was located near Dexter, Georgia in Laurens County on a typical Upper Coastal Plain farm employing intensive row crop agricultural practices. The typical row crop field is large and mechanically maintained. Little vegetation besides the planted crop is allowed to grow. Herbicide and insecticide application is done on a regular schedule, and periodic disking occurs when no crop is planted. Crops are often planted to the edges of the field leaving no transition zone to adjacent habitat, whether it be another field, wooded area, or roadway.

METHODS

Chick Mobility

A randomized complete block design was used, where each trial was a block. Eight blocks were established in the field margins of 3 fields enrolled in the BQI that were within 2 km of each other. Each block contained 3 bermudagrass densities: “High density” was categorized as having >20% coverage of bermudagrass "Low density" as >0–20% coverage, and "Zero density" as 0% coverage.

To evaluate mobility of bobwhite chicks, I purchased one-day-old bobwhite chicks and placed them in a single brooder with food and water to imprint on each other. The 8 blocks were uniquely numbered and assigned a color. Each density within a block was considered a run, and runs were labeled as high density, low density, and zero density. The chicks were randomly assigned to a color group and a corresponding leg band was placed on each. Each color group was randomly assigned its first run density.

I established a 2m-long track across the target bermudagrass density and placed each chick (n = 8) at the start. Chicks not participating in the trial were placed a 0.5 m past the finish line in a cardboard box so that that they would respond to the call of the "lost" chick and it would move toward the box. The front of the box was removed and replaced with screen wire to provide a direct line of sight between the test chick and the others. A taped locator call was played at the end of the run to increase the chances of drawing each chick naturally toward the finish line, and a divider was also fashioned inside the box to isolate the chicks that had completed the run.

One observer was the recorder and timer and sat with the box at the finish line operating the taped locator call. Another observer randomly chose a chick from the box and placed it at the start line. The timer was started and the second observer relayed the behaviors of the chick to the recorder. To reduce human intervention, observers kept as far from the chick as possible, while still being able to make direct observations. The taped call was started when the chick began calling. A cut-off time of 20 minutes was established to end an individual chick's run with no time recorded. Chicks moving toward the end were allowed to continue past the 20-

minute cut-off. If a chick strayed more that 2 m from the immediate vicinity of the run, it was picked up and allowed to restart. Times were recorded in minutes and seconds.

Runs were conducted in July from 7:00 to 10:00 and 18:00 to 21:00 EST, so the chicks were not exposed to excessive heat. Food and water were withheld 12 hours before the runs began so that the chicks would not begin feeding in early morning and be lethargic for the trials.

Trials were conducted twice, once when the chicks reached 5 days of age and again at 10 days of age. The colored leg bands ensured that the same group of chicks ran in the same block each time. All completed times were used in analysis. The results were analyzed by using Analysis of Variance and Tukey's Honestly Significant Difference (hereafter, Tukey's HSD) means separation test in Statistical Analysis System (SAS Institute 2000).

Temperature Analysis

In this experiment I used a paired plot design. Three sets of plots (3 x 3m) were established in each of the 3 fields. To test my hypothesis, each pair of plots had one area of bermudagrass (defined as having >75% coverage of bermudagrass) and a second area of annual weeds (defined as having >75% coverage of forbs). A single HOBO XT® Temperature Logger (Onset Corp.) was placed in each plot. Effort was made to place the sensor probe at ground level under the canopy of the vegetation. Hardware cloth cages were built around the temperature loggers to exclude small mammals.

External temperature was recorded at 24-minute intervals 7 August 2001 to 6 September 2001. Each logger had an effective range of –37 to 45 C. Although 1794 data points per plot were collected, only readings from 7:00 to 19:00 EST were used in analysis resulting in 897 data points per plot. The daily average daytime temperatures of the two types of plots were analyzed for significance using a paired *t*-test in SAS (SAS Institute 2000). Second, the percentage of daytime data points above the critical value of 39 C was calculated.

RESULTS

Chick Mobility

Mean completion times for 5-day-old chicks were calculated from 136 observations among the 3 densities (Table 4.1). No block effect was detected ($F_{2,7} = 1.60$, $P = 0.14$); however, a bermudagrass density effect was observed ($F_{2,7} = 6.79$, $P = 0.002$). Completion times for high and low density were greater than those times for zero density, but there was no difference shown between high and low density.

Mean completion times for 10-day-old chicks were calculated from 150 observations among the 3 densities (Table 4.1). No block effect was detected ($F_{2,7} = 0.76$, $P = 0.62$), and no bermudagrass density effect was detected ($F_{2,7} = 0.97$, $P = 0.38$).

Temperature Analysis

Mean daily temperatures within bermudagrass patches ranged from 34.3 to 35.0 C, with an overall mean of 34.5 C (±0.24 SE). Mean daily temperatures within forb patches ranged from 30.5 to 33.2 C with an overall mean of 31.6 C (±0.84 SE).(Figure 4.1). Mean daily temperature of bermudagrass patches was higher than in forb patches (t_4=3.34, $P = 0.03$).

The percentages of readings above the critical temperature for bobwhites in bermudagrass ranged from 32.8% to 38.1%, with an overall mean of 34.8% (±0.017 SE). The percentages of readings above the critical temperature for bobwhites in forb vegetation ranged from 8.3% to 26.2%, with an overall mean of 14.7% (±0.058 SE). A greater number of daytime temperature points were above the critical temperature of 39 C in bermudagrass patches than in forb patches (t_4=3.35, $P = 0.03$).

DISCUSSION

Chick Mobility

While high-density and low-density bermudagrass slowed chicks when they were younger, there was no difference among bermudagrass densities when the chicks reach 10 days of age. I expected that high-density grass would slow the chick's movement, but the finding no difference between high density and low density was surprising. I expected a step-wise increase in completion times with increasing bermudagrass density. These results suggest bermudagrass inhibited movement 5-day old bobwhite chicks. At 10 days old bobwhite chicks are quickly approaching the age of their first flight (approximately 14 days). Their legs are stronger and they have a better-developed sense of balance making it easier to navigate the areas of bermudagrass. The first few days of life are crucial because they are associated with the highest rates of mortality. The young are balancing food and water requirements, predation avoidance, and their thermal environment and energy utilization. The importance of open ground for bobwhite survival was noted by deVos and Mueller (1992). It is still unclear to what extent the inhibitory nature of bermudagrass effects 5-day old chicks, but the results suggest that mechanical effects on mobility could have a negative impact on the chicks, thereby decreasing quality of habitat created by quail management programs.

Temperature Analysis

As noted by Forester *et al.* (1998) bobwhites tend to select habitats cooler than what is randomly available, so patches of bermudagrass will most likely be avoided by adults. Chicks, being unable to self-regulate temperature (Borchelt and Ringer 1973), will most likely be led away from areas with high bermudagrass densities by the hen. This fragments and reduces the extent of habitat available to broods for feeding and resting. Chicks will have to move over a greater area to find food resources in patchy and fragmented suitable habitats. This has the potential to reduce chick survival as an indirect result of daily outside temperature.

The findings of this data analysis further support the argument that bermudagrass functions as a heat trap. The critical temperature of 39 C represents the point at which heat dissipation is no longer effective (Guthery *et al*. 2000). At this temperature and above other methods of cooling must be employed or death will soon result. While the temperature still reaches the critical point in annual weeds, there are fewer temperature points in the lethal range so that more of the habitat is useable. The variability shown in the annual weeds is possibly due to the patchy shading presented by the vegetative species present in those areas. Thermal stress will again fragment the available habitat. In a fragmented habitat, adults must move their broods farther and longer to obtain the same amount of food. This again has the potential to reduce survival of chicks during critical periods.

MANAGEMENT IMPLICATIONS

From the results of this study, the importance of controlling bermudagrass in the areas of established habitat under the BQI management is apparent. These results further demonstrate the need to continue to address grass issues within the BQI program as they relate to brood habitat in particular. The most vulnerable time in a chick's life is the early days (Guthery 2000). Mortality is highest when the chicks are youngest and is why they are most vulnerable to the effects of heat and mechanical impediment to movement. Bermudagrass presence fragments the habitat available to the chicks for feeding, loafing, and avoiding predators thus reducing their chances of survival. This research further suggests taking steps to increase the presence of forbs, particularly beneficial species, will allow for less habitat fragmentation and higher survival rates of young in the BQI managed habitats. Although both of these factors have been anecdotally described as having an important affect of quail chicks, this is the first experimental evidence of the mechanisms by which they are affected.

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Table 4.1. Mean time (minutes ± SE) required by 5 and 10 day-old bobwhite quail chicks to complete a 2m track through vegetation containing zero, medium, or high densities of bermudagrass. Means with the same letter are not different (Tukey's HSD, $P < 0.05$).

	Bermudagrass Density		
	Zero (0%)	**Medium (>0%-20%)**	**High (>20%)**
Chick Age	**Mean (SE)**	**Mean (SE)**	**Mean (SE)**
5 Days	0.77 (0.095) A	1.17 (0.094) B	1.22 (0.093) B
10 Days	0.61 (0.052) C	0.67 (0.056) C	0.56 (0.059) C

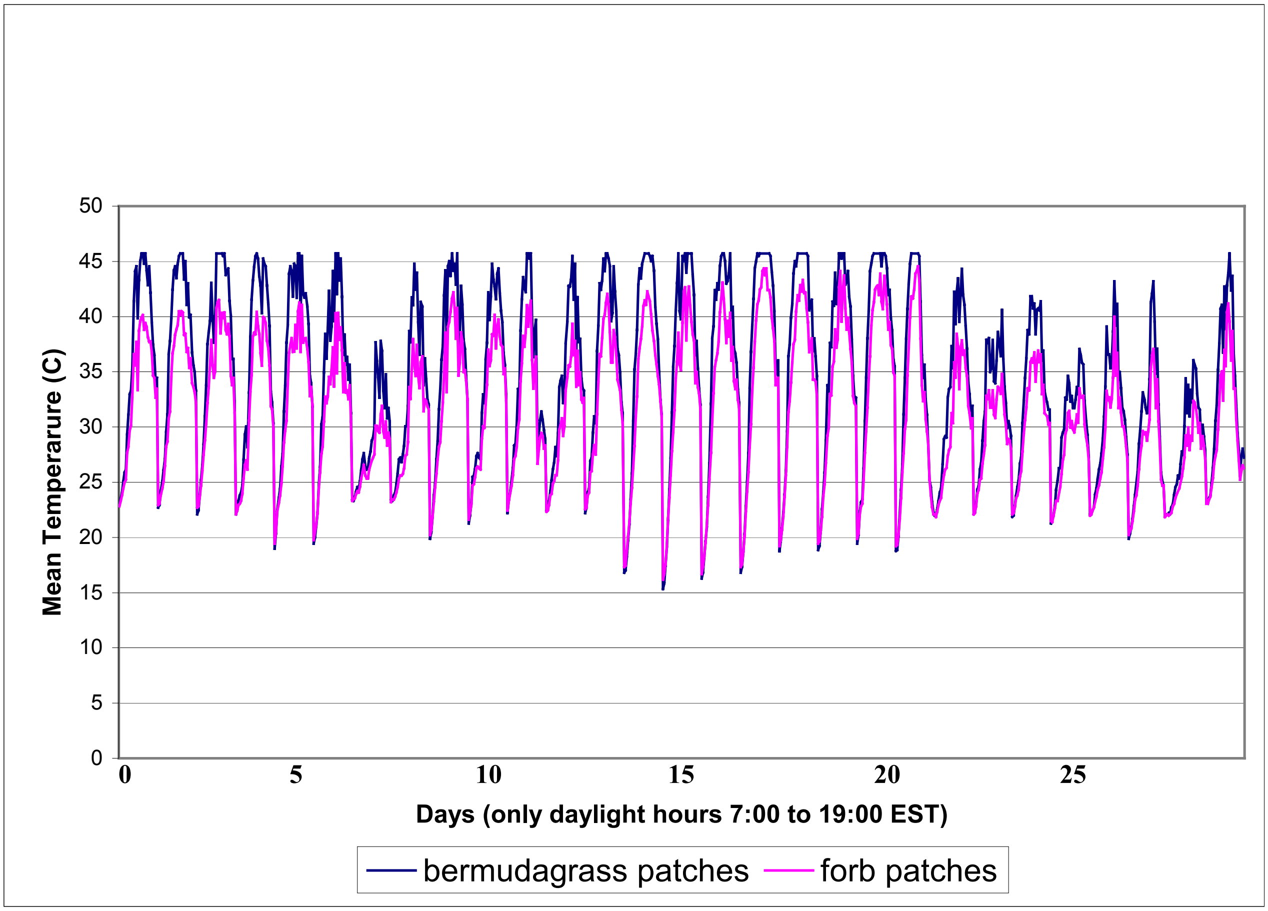

Figure 4.1. Mean hourly temperatures during daylight hours for bermudagrass and forb patches in BQI enrolled fields in the Upper Coastal Plain of Georgia from 7 August 2001 to 6 September 2001. Daytime temperatures only displayed (7:00 to 19:00 EST) showing bermudagrass patches with a higher mean daily temperature and more time above the 39 C threshold than forb patches.

CHAPTER 5

SUMMARY

The state of Georgia was once known as the "Quail Capital of the World" due to the abundance population of Northern Bobwhite (*Colinus virginianus*) (bobwhite). However, bobwhite populations have declined during at least the last 40 years (Brennan 1991). To address this decline, Georgia's General Assembly worked with the Georgia Department of Natural Resources (GA-DNR) to create and fund the Bobwhite Quail Initiative (BQI), which was implemented during the autumn of 1999. The purpose of this incentive program was to restore quality habitat for bobwhite in farmland ecosystems (GA DNR 1999). The program was based in the Upper Coastal Plain, and by early 2002, a total of 17 counties were included in the program with more than 150 landowners and farmers participating.

Quality brood-rearing habitat is one of the key components for maintaining bobwhite populations, and so it was necessary to assess whether current BQI management regimes generated quality brood habitat. To determine this, I examined managed areas from two perspectives. First, I measured vegetative response to BQI habitat management to assess habitat quality for bobwhite broods. Because invasive plant species, such as bermudagrass (*Cynodon dactylon*), were thought to reduce brood habitat quality, I documented invasion and potential negative impacts of invasive plants on brood ecology to assess the value of BQI habitat management. As a second objective, I explored control options for potential problem plant species, particularly bermudagrass. The overall goal of this research was to ascertain whether brood habitats generated by BQI management are likely to increase recruitment.

This study demonstrated that beneficial plants for quail management were present, but many very important ones, such as beggarweed and partridge pea, were not typically present in our sample. New management objectives, such as planting of desirable species, may be incorporated into the BQI to encourage regeneration of desired species making these linear strips more suitable for bobwhites. Broomsedge, an important nesting substrate, was not recorded. Ragweed was found to be present, and it is important for providing escape cover from predators, foraging, and solar heating. Invasive plants, such as bermudagrass, were found even in the first year after management

Management plans can be tailored to effect changes in specific fields or across broad regions based on the species lists compiled from this project. Categorizing the growth characteristics of treatment areas may allow biologists to identify the specific areas that demonstrate desirable growth. These areas can be further studied based on local conditions. By promoting desirable species, like beggarweed, partridge pea, ragweed, and *Rubus* spp., and taking steps to eradicate the undesirable species, such as bermudagrass and crab grass, the bobwhite habitat once so abundant can again be present in the Upper Coastal Plain of Georgia.

Management of narrow strips around agricultural fields presents many challenges. Within the constraints of the BQI management program, I realized that complete removal would not be cost effective. However, a single treatment with grass specific herbicides was not sufficient to create substantial changes in bermudagrass invasion. It appears that more aggressive and costly bermudagrass control will be required. I suggest multiple spray treatments, treatments in fall, or cool season cover crops might improve quality of these strip habitats.

From the results of this study, the importance of controlling bermudagrass in the areas of established habitat under the BQI management is apparent. These results further demonstrate the need to continue to address grass issues within the BQI program as they relate to brood habitat in particular. The most vulnerable time in a chick's life is the early days (Guthery 2000). Mortality is highest when the chicks are youngest and is why they are most vulnerable to the effects of heat and mechanical impediment to movement. Bermudagrass presence fragments the habitat available to the chicks for feeding, loafing, and avoiding predators thus reducing their chances of survival. This research further suggests taking steps to increase the presence of forbs, particularly beneficial species, will allow for less habitat fragmentation and higher survival rates of young in the BQI managed habitats. Although both of these factors have been anecdotally described as having an important affect of quail chicks, this is the first experimental evidence of the mechanisms by which they are affected.

Overall this project produced encouraging results. Beneficial species were found, and the absence of some desirables was also noted so future efforts can focus on their propagation. Invasive species, believed to be present were located. I was able to quickly show that a low-intensity, low-input solution was not viable. Suspicions about the invasive species influence on bobwhite chicks were confirmed. Bermudagrass was found to act as a heat trap and a mechanical barrier to movement. I can only hope that these findings and suggestions will be taken into consideration as management plants are revised for the BQI future development.

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