CRAIG GEORGE WHITE
Modeling Avian Response to Changes in Land-Use Practices at the Landscape Level
(Under the direction of SARA H. SCHWEITZER)

I examined the influence of the landscape structure and composition, as well as modifications to Conservation Reserve Program (CRP) pine plantings, on the avian community (northern bobwhite [*Colinus virginianus*], songbirds, and eastern wild turkey [*Meleagris gallopavo silvestris*]) in a Southeastern landscape dominated by agricultural and silvicultural practices. Modifications to CRP pine plantations (thinnings and openings) were designed to simulate current CRP recommendations for already established pine plantings. Predictive models were developed based on correlation of habitat characteristics and nest locations, avian indices, and wildlife movements. The study was aided by the use of radio-telemetry, GIS, remote sensing, and multivariate analysis. Components of landscape structure that were important in predicting nest site selection of bobwhite at different spatial scales were patch density and open canopy planted pine. Songbird abundance within pine plantings was predicted by patch density within the landscape. The percentage of early successional and hardwood habitat and the interspersion of habitat types in the landscape predicted songbird richness within pine plantings. For wild turkey, hardwood land cover was overwhelmingly the best predictor of female breeding, female post-incubating, and male post-breeding activity. The male wild turkey breeding model predicted (81.35% after cross-validation) avoidance of field/hardwood edge and agriculture/closed-canopy planted pine edge, and shorter distances to closed-canopy planted pine/field edge during the spring than random locations. I also provided land managers with accessibility to a model developed from vector GIS data, which predicts wild turkey nest locations using raster GIS data. The ability of the model to discriminate nesting sites from random sites using satellite data was almost equal to model results using original vector data (73.7 % vs. 79.0 %). Results from this study support mechanically modifying CRP pine plantings to include openings and low tree densities and thus create a diverse vegetative structure within the plantings. Results also indicated the importance of considering the mosaic of habitat types in the landscape immediately around pine plantings. This study is one of the first to examine the effects that modifications to CRP, pine plantations, and subsequent landscape changes have on populations of northern bobwhite, songbirds, and eastern wild turkeys in the Southeast.

INDEX WORDS: Avian abundance, Conservation Reserve Program (CRP), Eastern wild turkey, Geographic Information System (GIS), Habitat, Logistic regression, Nesting, Northern bobwhite, Predictive Models, Remote sensing, Richness, Silviculture, Southeastern Coastal Plain

MODELING AVIAN RESPONSES TO CHANGES IN LAND-USE PRACTICES AT THE LANDSCAPE LEVEL

by

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

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Conservation Reserve Program

Few of us remember the Dust Bowl of the 1930s and the changes it brought to our nation. Even fewer are cognizant of its lingering effects. The Dust Bowl of the 1930s resulted in several conservation initiatives designed to curb soil erosion, including the Soil Bank Act and the Cropland Adjustment Program of 1956 (Langner 1989, Farm Service Agency 1997). These conservation initiatives impacted farming practices and subsequently wildlife populations. Since the passages of these and similar initiatives (see Langner 1989) 2 things have occurred that continue to affect agricultural lands and wildlife populations in agricultural settings, respectively. First, soil continues to be lost at an estimated 3 billion tons/year (Farm Service Agency 1997). Second, agricultural technology advancements have led to changes in farm structure and production practices (Capel et al. 1995). Primarily, field sizes have increased, larger acreage is planted to monocultures, and marginal land that once provided important wildlife habitat is brought under crop production (Langner 1985).

As a result of continued soil losses in the 1980s due to erosion, the Conservation Reserve Program (CRP), a large-scale cropland retirement program, was created as part of the 1985 Food Security Act (Farm Bill). It was conceived as a voluntary program that offered agricultural landowners annual rental payments and cost-share assistance for 10 to 15 years. Primary purposes of the CRP were to control commodity supply and long-term soil erosion. The federal government supplied annual rental payments at the land's going rental rate. In addition, the government helped finance conservation practices established on land enrolled into the CRP. The 1985 Farm Bill evolved into a multipurpose conservation program and was amended in 1990 and 1996 (McKenzie 1997). Amendments in 1996 created the Environmental Benefits Index (EBI) to quantify and rank land management proposals being considered for enrollment or re-enrollment. Scores were based on the expected benefit to wildlife habitat, soil resources, water quality, and other resource concerns (Farm Service Agency 1997). Efforts by wildlife conservation enthusiasts resulted in wildlife conservation being added as a third priority (Helinski 2000).

Landowners enrolled in the CRP may implement 1 or more different vegetative cover and management practices. Common conservation practices include planting of wildlife -beneficial grasses and legumes (CP1), establishing permanent native grasses (CP2), tree planting (CP3), establishing permanent wildlife habitat (CP4), and managing trees and vegetative cover that are already established (CP11) (Issacs and Howell 1988).

Nationwide, >14 million ha of agricultural land were enrolled and 12 million ha were in active contracts by 1997 (Farm Service Agency 1997). More than 12 million ha of agricultural land have been converted to grasses as part of the CRP. The principal conservation practice chosen by landowners in the Southeast was tree plantings (CP3). By 1 January 1997, Southeast landowners had enrolled 830,202 hectares of land into a tree conservation practice. The hectares put into tree plantings represented 56.8% of the total CRP enrollment in the Southeast and accounted for 87.3% of the nationwide hectares planted to trees. The 3 Southeastern states with the highest percentages of CRP-enrolled land planted to trees were Georgia (91.3%), Florida (90.5%), and South Carolina (78.9%) (Farm Service Agency 1997). Since 1995, the contracts for land enrolled into the CRP have been expiring. Financially, landowners would be well served to grow trees planted under the CRP, CP3 category to maturity (Dangerfield et al. 1995). A landowner who re-enrolled their tree plantings into the CRP in a CP11 category, would also continue to receive rental payments from the federal government. However, due to the use of the EBI since 1996, a landowner wishing to re-enroll tree plantings into the CRP would increase their chance of enrollment by thinning, or creating openings in a pine plantation to improve the stands for wildlife habitat (Burger 2000).

The potential benefit of the CRP to wildlife is tremendous but the realized benefits to wildlife will depend on the landowner or manager (Miller and Bromley 1989). Non-industrial, privately owned forests are often passively managed (Alig et al. 1988). This does not need to be the case. Miller and Bromley (1989) reported that 72% of Virginia CRP participants were interested in improving wildlife habitat on their enrolled land. Alig et al. (1988) stated that some landowners highly value conservation, protection, and preservation. For the most part, benefits to wildlife from conservation programs have largely been a secondary effect (Langner 1985). Managing habitat for wildlife is also an economically rewarding enterprise as well. The Farm Service Agency (1997) reported that U.S. Department of Agriculture (USDA) and U.S. Fish and Wildlife Service (USFWS) estimates place the benefits from consumptive and nonconsumptive wildlife use as a result of the initial CRP enrollment at well over $7 billion dollars. Williams and Mjelde (1994) conducted a financial analysis of quail hunting within the CRP and found that with little management, leased CRP lands would provide greater net present value than would CRP enrollment alone. Unfortunately, not providing information to CRP participants about wildlife options may limit landowners and managers from implementing wildlife habitat improvements (Miller and Bromley 1989, Kurzejeski et al. 1992).

In general, the CRP was considered by many to be one of the best conservation programs established in the U.S. Soil erosion has been reduced, and there were many hidden benefits including increased connectivity between woodlots, enhanced seed dispersal capabilities among woodlots, maintenance of biodiversity, improvements in carbon flux, aesthetics, and improved wildlife habitat (Dunn et al. 1993, Farm Service Agency 1997). However, wildlife biologists in the southeastern U.S. have been disappointed with the CRP. This is primarily because large areas of cropland in the Southeast have been converted to pine plantations. Biologists believe that the conversion of cropland to pine plantations has had more of a negative impact on plant and wildlife diversity, than a positive impact (Allen 1993, Capel et al. 1995, Carmichael 1997). The interspersion of fields, hardwood stands, pine plantations, etc., combine to form a landscape mosaic of habitat types available for wildlife. The conversion of cropland to pine plantation will have some effect on the landscape mosaic. However, little work has been done to evaluate the effects of the changing landscape mosaic on wildlife use and movements at the landscape level.

The effects in the Southeast of the conversion of thousands of hectares of land into the CRP are felt on at least 2 land management levels. On a regional and landscape level, forest acreage in the Southeast has remained relatively stable but the composition and quality of the forest have changed, resulting in displacement of diverse hardwoods and small crop fields by expanding pine plantations (Helinski 2000). On a patch level, most CP3 lands in the Southeast were planted to loblolly pine (*Pinus taeda*) at densities of about 1,793 trees/ha (726 trees/acre). During the first few years after planting a pine plantation, grassland and early successional bird species increase (Darden et al. 1990). After a few years, the grassland and early successional bird species give way to shrub-successional species, which peak by around 10 years (Burger 2000). The changes in wildlife composition that use pine stands mirror the changes in vegetation within a stand. Canopy closure within pine stands occurs after 8-10 years (Johnson et al. 1974, Felix et al. 1986, Melchoirs 1991, Allen 1994). These monotypic pine stands provide few benefits to wildlife once the canopy closes, and mid- and under-story vegetation are shaded-out (Johnson et al. 1974, Allen 1994).

In summary, pine stands that are not managed effectively for wildlife and timber appear to offer few benefits to wildlife. With periodic management treatments, however, most plantations would provide a greater diversity of habitat (Allen et al. 1996). CRP pine plantations are owned and managed by non-industrial private forest landowners with varying interests. Intensively managed CRP pine plantations can provide within-stand diversity but the cumulative decisions made by multiple owners can affect long-term quality of habitat on a regional scale.

Management of CRP pine plantations should ideally benefit wildlife, not jeopardize the CRP status of a pine plantation, and not significantly lower the economic return of the timber. Thinning pine stands and/or creating gaps in stands are methods that may meet these criteria. Precommercial thinning in pine stands is a common practice and is encouraged under the current Farm Bill. Thinning pine stands is an accepted practice for improving wildlife habitat because it opens the canopy and promotes growth of herbaceous and shrubby vegetation (Cushwa et al. 1969, Johnson et al. 1974, Conroy et al. 1982).

Avian Wildlife Species and Modeling

The interspersion of fallow fields, hardwood stands, pine plantations, and croplands, found in the southeastern United States creates the landscape mosaic of habitat types available to wildlife. Allen (1993) reported that the establishment of pine plantations under the CRP might have eliminated thousands of acres of high-quality nesting, brood rearing, and foraging habitat for birds in the Southeast. However, little work has been done to evaluate the effects of the changing landscape mosaic on wildlife use and movements.

Songbirds.— The USFWS documented an increase in several wildlife species in the Midwest benefiting from CRP plantings (primarily CP1 and CP2). Wildlife species experiencing increases in numbers included waterfowl, grasshopper sparrow (*Passerculus sandwichensis*), lark bunting (*Calamospiza melanocorys*), eastern meadowlark (*Sturnella magna*), ring-necked pheasant (*Phasianus colchicus*), elk (*Cervus elaphus)*, mule deer (*Odocoileus hemionus*), and white-tailed deer (*O. virginianus*) (Farm Service Agency 1997). Ryan et al. (1998) reviewed literature to assess the impact of CRP on bird populations in the central USA and found that more than 90 species used CRP habitat. Indeed, multiple studies have estimated the effect of the CRP on bird populations in the midwestern grasslands (Burger et al. 1990, Hayes and Farmer 1990, Stauffer et al. 1990, Johnson and Schwartz 1993, Reynolds et al. 1994, Hanowski 1995, Millenbah et al. 1996, Best et al. 1998, Hughes et al. 2000). However, the response of avian species, particularly songbirds (passerines), to CRP pine plantations converted from agricultural lands and the subsequent thinning of CRP pine plantations, has received little quantitative attention (Burger 2000).

Early successional bird species, such as the prairie warbler (*Dendroica discolor*) and the indigo bunting (*Passerina cyanea*) are of concern in the Southeast due to declining numbers (McKenzie and Riley 1995, Sauer et al. 1999, Burger 2000). Young pine plantations created by the CRP in the Southeast would be expected to benefit early successional birds. Johnson and Landers (1982) pointed out that avian diversity and species richness tends to increase with stand age until canopy closure, at which point they decline until the stand reaches sawtimber size (Darden et al. 1990). Thus a young pine plantation provides diversity of herbaceous and horizontal cover for early successional species but as it ages the canopy closes resulting in a decrease in vegetation diversity (Johnson et al. 1974). As the pine plantation reaches sawtimber size avian diversity increases, but this increase is not in regionally declining grassland and early successional species (Burger 2000). Mid-rotation management such as a thin or burn could open the canopy and result in an increase of vegetative diversity (Cushwa et al. 1969, Johnson et al. 1974, Conroy et al. 1982, Allen 1996, Burger 2000). Others (Johnston and Odum 1956, MacArthur and MacArthur 1961, and Johnson 1975) have discussed the positive relationships between measures of avian diversity and measures of habitat diversity.

Diversity within pine plantations is not the only predictor of songbird abundance and diversity. The value of a pine plantation as wildlife habitat may be affected by its proximity to other land uses and vegetation types (Allen 1996). Quantitative evaluations of landscape influences on the avian community have recently been conducted. For example, Kilgo et al. (1997) examined the effects of forest fragmentation (i.e., hardwood fragments surrounded by agricultural habitat) on bird communities in the Southeastern Coastal Plain. Robinson et al. (1995) evaluated the effect of regional forest fragmentation and the nesting success of migratory birds in five midwestern states. Penhollow and Stauffer (2000) examined the relationship of bird assemblages and species to habitat patterns across a small section of the Virginia landscape composed of a mosaic of habitat elements. However, no one has evaluated the relationship between the avian community and the landscape around monitored CRP pines.

Due to declining early successional songbirds and the lack of quantitative analysis, a need was recognized to determine the responses of songbirds to thinning and creating openings in CRP pine plantations in pursuit of maintaining habitat suitable for a variety of wildlife species. We expected the populations of resident and migratory birds to be affected by within-stand modification of CRP pine stands and by interspersion of habitats across the agricultural/silvicultural landscape. To assess the influence of landscape structure and composition, as well as modifications to CRP pine plantations, on the avian community during the spring breeding period, we determined which large-scale habitat elements (Penhollow and Stauffer 2000) influenced bird community richness and abundance in these pine plantations. We developed quantitative models for avian richness, avian abundance, and migratory strategy and nesting guild abundance based on landscape measurements and CRP approved modifications. This study was one of the first to examine the avian community in modified CRP pine stands, and the first to examine the relationship between the avian community and the landscape around monitored CRP pines.

Northern Bobwhite.—Within the changing landscape mosaic of the Southeast, northern bobwhite (*Colinus virginianus*) require nesting habitat, brood-rearing habitat, feeding areas, roosting areas, and appropriate escape cover (Stoddard 1931, Rosene 1969, Schroeder 1985). Areas disturbed every 1-4 years may meet these life requirements (Rosene 1969, Melchiors 1991, Landers and Mueller 1992, Stewart et al. 1997, Thackston and Whitney 2001). Bobwhite are considered residents of several habitat types including pine woodlands, woodland edge, shrubs, agricultural fields, pastures, rangeland and fallow fields (Carroll 1994:425) and have been declining over much of their range (Brennan 1991, Church et al. 1993). Brennan (1991) noted that the irony of the decline is that for over half a century effective habitat management has been known for the bobwhite. Brennan summarized various reasons given for the decline in bobwhite but emphasized that all available evidence points to 1 reason; inferior habitat. One way in which habitat has become inferior for bobwhite is by the intensification of agriculture and silviculture which has resulted in increased field sizes, monoculture plantings, and loss of diversity within agricultural (Langner 1985) and silvicultural dominated landscapes (Helinski 2000).

A few studies have evaluated the potential effects that the CRP has had on available habitat for bobwhite. Hays and Farmer (1990) found inconclusive evidence as to whether conversion of cropland to pine plantations resulted in a reduction of bobwhite winter food supply. Stauffer et al. (1990) reported that field data and simulations of CRP changes suggested a substantial decline in the quality of habitat for quail as greater amounts of cropland are converted to CRP pine plantations. However, in their model they did not evaluate the spatial configuration of the various habitats surrounding or bordering pine plantations. Roseberry et al. (1994) used remote sensing, a geographical information system (GIS), and habitat modeling to assess the potential impact of the CRP on bobwhite habitat. Their study area was in southeastern Illinois and the CRP land within their study area primarily consisted of introduced grasses and legumes. Roseberry et al. (1994) determined that contribution of CRP fields to habitat quality would depend on several things, including the juxtaposition of CRP fields with other habitat components. Burger et al. (1990), working in northern Missouri and in CRP fields established to grass and wildlife habitat conservation practices determined that newly established fields provide roosting and brood rearing habitat and older established fields may provide nest habitat. The CRP in general has been considered highly beneficial for many wildlife species (Farm Service Agency 1997), but Ryan et al. (1998) reviewed the literature available to them and reported that little evidence indicated that availability of CRP resulted in a positive population response by bobwhite.

Although Roseberry and Klimstra (1984) are repeatedly cited by various studies (e.g., Burger et al. 1990, Stauffer et al. 1990) for noting that habitat management for bobwhite should consider the juxtaposition and interspersion of habitat types, few studies have quantified the proper juxtaposition and interspersion of habitat for bobwhite needs. Roseberry and Sudkamp (1998) assessed the suitability of landscapes for bobwhite in Illinois by comparing landscape structure with indexes of bobwhite abundance. However, no work has been done to evaluate the relationship of bobwhite and landscape structure composed of agricultural and silvicultural practices in the Southeast.

Potentially the CRP would provide a diversity of habitat types in a landscape that could benefit bobwhite. The suitability of pine plantations and other habitat cover types for bobwhites is affected by the spatial configuration of the land cover types (e.g., Burger et al. 1990, Stauffer et al. 1990). Allen et al. (1996) noted that spatial location of pine plantations can contribute to landscape-level habitat priorities addressing fragmentation and habitat composition. The increased ability of researchers to evaluate habitat type configuration, composition, and fragmentation on wildlife phenomena is evident by the subject matter of recent literature. The literature reveals a trend toward using geographic information systems (GIS), patch or landscape metrics, multivariate statistics, and modeling to examine the relationship between wildlife locations and habitat type (Roseberry et al. 1994, Robinson et al. 1995, Ripple et al. 1997, Roseberry and Sudkamp 1998, Merrill et al. 1999, Miller et al. 2000, Penhollow and Stauffer 2000).

We used GIS and spatial analysis software to calculate class (i.e., all habitat patches of similar vegetation characteristics) and landscape measurements around bobwhite nest sites. Because the association between bobwhite nest sites and landscape structure may be different among spatial scales we evaluated the relationship at 4 different scales. Logistic regression, a multivariate statistical technique, was used to spatially model bobwhite nest sites' relationship to structure within the surrounding landscape. Our objective was to determine components of landscape structure(s) important in predicting nest site selection of bobwhite at different spatial scales.

Eastern Wild Turkey.—Use of land cover types in the Southeast by eastern wild turkey (*Meleagris gallopavo silvestris*) has been well documented in heavily timbered landscapes (Wigley et al. 1985, Exum et al. 1987, Burke et al. 1990, Hurst and Dickson 1992, Wunz and Pack 1992, Palmer et al. 1993, Allen et al. 1996, Miller et al. 1999). It is generally accepted that mature stands of mixed hardwoods, with relatively open understories, interspersed with scattered clearings and groups of sawtimber-sized conifers combine to form high quality wild turkey habitat in the Southeast (Allen et al. 1996). However, the benefit to wild turkey populations of even-aged short rotation pine plantations in heavily timbered landscapes is variable and use is dependent upon sex and age of turkeys (Wigley et al. 1985, Exum et al. 1987, Bidwell et al. 1989, Burke et al. 1990, Allen et al. 1996, Morgan 2000). Use of pine plantations by wild turkeys within a mixed agricultural and timber landscape, such as that created by the CRP, has only recently been analyzed quantitatively and reported (Morgan 2000).

It is recognized that the suitability of pine plantations and other land cover types for wild turkey use and benefit are affected by the spatial configuration of land cover types (Felix et al. 1986, Holbrook et al. 1987, Allen et al. 1996). The increased ability of researchers to evaluate habitat type configuration, composition, and fragmentation on wildlife phenomena is evident by the subject matter of the recent literature. The literature reveals a trend toward increased use of GIS, patch or landscape metrics, multivariate statistics, and modeling to examine the relationship between wildlife locations and habitat type (Roseberry et al. 1994, Robinson et al. 1995, Ripple et al. 1997, Roseberry and Sudkamp 1998, Merrill et al. 1999, Miller et al. 2000, Penhollow and Stauffer 2000).

We used GIS to calculate distance measurements to the nearest land cover types and land cover edge types available in an agriculture/silviculture landscape. Logistic regression was used to spatially model eastern wild turkey use of habitat types found within the landscape (Miller et al. 2000). Our objective was to determine responses of eastern wild turkey to the landscape configuration and composition available to them as a result of past land management decisions, including those facilitated by the CRP over the last 15 years.

GIS and Modeling.—Recent techniques used by wildlife researchers to assess the effects that habitat fragmentation at the landscape level have on wildlife include the analysis options provided by GIS. Roseberry et al. (1994) assessed the potential impact of converting agriculture lands to CRP plantings in the Midwest on northern bobwhite habitat using remote sensing, GIS, and habitat modeling. Using GIS, Ripple et al. (1997) studied the landscape composition and pattern around northern spotted owl (*Strix occidentalis caurina*) nests in southwestern Oregon. Recently, Merrill et al. (1999) used GIS to analyze land-use patterns surrounding greater prairie-chicken (*Tympanuchus cupido pinnatus*) leks in northwestern Minnesota.

Other wildlife researchers have incorporated landscape metrics into their studies to evaluate the effect of patch (a single homogeneous landscape unit), class (set of similar patches), and landscape (mosaic of interacting patch types) characteristics on other wildlife phenomena (McGarigal and Marks 1995). Heinen and Cross (1983) described a method to measure habitat type interspersion, juxtaposition, and spatial diversity from cover-type maps to assess the quality of the wildlife habitat. Robinson et al. (1995) used FRAGSTATS (McGarigal and Marks 1995) computer program to calculate the percentage of forest cover, forest interior, and forest patch size in 9 Midwestern states in a study of regional forest fragmentation and nesting success of migratory birds. Roseberry and Sudkamp (1998) combined the use of classified satellite imagery and FRAGSTATS software to assess the suitability of landscapes for northern bobwhite.

Recent literature reveals a trend to use GIS, remote sensing, landscape variables, and/or multivariate statistics to evaluate habitat land cover conditions (Dettmers and Bart 1999, Hill and Bleich 1999, Johnson et al. 1999, Bogaert et al. 2000, Fox et al. 2000). For example, Penhollow and Stauffer (2000) used stepwise multiple regression and stepwise logistic regression to determine which large-scale habitat measures were associated with community performance of Neotropical migratory birds. To generate habitat metrics they used GIS coverages in the vector version of FRAGSTATS. Miller et al. (2000) modeled habitat selection for eastern wild turkeys in Mississippi using vector GIS coverages generated from aerial photographs and 7.5 min quadrangles, and logistic regression.

Morgan (2000) used GIS, logistic regression, and FRAGSTATS*ARC™ (Pacific Meridian Resources 2000) to analyze landscape level influences on nest site selection by wild turkeys. The goal of his research was to develop a robust, simple model that could predict nesting locations in a large geographic area. Such a model could provide a land manager with an effective means of monitoring wild turkey nesting site availability across the southeastern landscape. The time required to digitize and maintain the vector coverages for large landscapes, however, hinders model use. Managers need a time-efficient and inexpensive method to populate models like the nesting habitat model with spatial variables. Obtaining spatial variables from satellite imagery can be more time efficient, but conversion between vector and raster can affect landscape indices. Bettinger et al. (1996) found that measures are sensitive to the grid cell size used in the conversion process, and found that polygon areas were significantly modified when converted from vector-raster-vector coverages when using grid cell sizes of 20 m and 30

m. Therefore, the goal of my research was to determine whether reflectance data collected by satellite, in raster format at a 30-m resolution, could accurately produce the spatial variables required to populate a spatial model that was created using vector polygons digitized at a 1:3,000 meter scale.

We compared the percentage of fallow field in each buffer as determined from vector data and as calculated from classified raster data. We also compared the predictive power of the model populated with spatial data from the digitized, vector coverage and the classified, raster coverage. In addition, we report, using generic language, our methods for making these comparisons between raster and vector data to encourage the use of such spatial models by land managers.

Summary of Objectives

The USFWS has documented an increase in several wildlife species in the Midwest benefiting from CRP plantings (primarily CP1 and CP2; Farm Service Agency 1997). However, the response of avian species to CRP pine plantations converted from agricultural lands has received little quantitative attention (Burger 2000). Because there are no data on responses of wildlife species to CRP practices implemented in the Southeast, yet populations of several avian species dependent on early successional habitat are declining at significant rates (Burger 2000), it was imperative to examine the associations between the establishment of CRP pine plantations and management recommendations, and responses of the avian community. Specific species studied were northern bobwhite, songbirds (passerines), and eastern wild turkey. I expect the populations of resident and migratory birds to be affected by the within stand modification of CRP pine and by the interspersion of habitats across the agricultural/silvicultural landscape. Likely, those species with the largest home ranges (i.e., wild turkey) will be more affected by landscape-interspersion than by within stand changes.

In 1998, a research project was undertaken to assess the influence of thinning and openings in CRP pine stands and the landscape composition and structure on wildlife. Thinnings were designed to simulate current CRP recommendations for already established pine stands. Our treatments were, 1.) thinning to ≤ 741 trees/ha (row thin), 2.) creating openings in 20% of a stand's area and thinning to ≤ 741 trees/ha (open and row thin), and 3.) no mechanical modification to pine plantations (control). Objectives of this study were: 1) to assess the influence of the landscape structure and composition, as well as modifications to CRP pine plantations, on the avian community (northern bobwhite, songbirds, and wild turkey); 2) develop predictive models based on correlation of habitat characteristics and nest locations, avian indices, and wildlife movement; and 3) provide land managers with accessibility to a predictive model developed from vector GIS data and populated with raster GIS data. Completing the objectives were aided by the use of radio-telemetry, GIS, remote sensing, and multivariate analysis. Hypotheses tested were: 1) songbird community richness and abundance, as well as migratory strategy and nesting guild abundance were not predictably based on the landscape structure within and surrounding CRP pine plantations; 2) landscape structure would not explain differences, within and across landscape scales, between actual northern bobwhite nest sites and random locations; and 3) eastern wild turkeys, across seasons and sexes, show no preference for any one land cover edge type over another. This study is one of the first to examine the effects that modifications to CRP, pine plantations, and subsequent landscape changes, have on populations of northern bobwhite, songbirds, and eastern wild turkeys in the Southeast.

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CHAPTER 2

PREDICTING AVIAN RICHNESS AND ABUNDANCE IN MECHANICALLY TREATED CONSERVATION RESERVE PROGRAM PINE PLANTINGS IN THE SOUTHEAST USING LANDSCAPE METRICS[1]

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ABSTRACT: The Conservation Reserve Program (CRP) altered the interspersion of habitat cover and proportion of habitat cover available to wildlife in southeastern landscapes. The use of CRP pine plantings in the Southeast by the avian community, particularly passerines, has received little attention among researchers, and the effects of the surrounding landscape mosaic on avian abundance and richness have not been evaluated. The 1996 Farm Bill encouraged landowners wishing to re-enroll their tree plantings into the CRP to thin or create openings in them. We used multiple linear regression to model the response of the avian community to mechanically modified CRP and CRP-like tree plantings (all loblolly pine [*Pinus taeda*]) and to the landscape within 250 m of the pine plantings. Patch density within the landscape was a significant predictor of avian abundance. Percentage of early successional and hardwood habitat and interspersion of habitat types in the landscape were significant predictors of avian richness. Patch density, percentage of early successional habitat, density of patch richness within the landscape, row thin treatments, and study location were significant predictors of nesting guild and Neotropical migrant abundance within CRP pine plantings. Results from this study support mechanically modifying CRP pine plantings to include openings and low tree densities and thus create a diverse vegetative structure within the plantings. Results also indicated the importance of considering the mosaic of habitat types in the landscape immediately around pine plantings. In areas dominated by large agricultural fields, fragmentation of these fields by creation of CRP pine plantings with thinnings and openings may create habitat more suitable for some early successional songbird species.

INTRODUCTION

The CRP, a large-scale cropland retirement program, was created as part of the 1985 Food Security Act (Farm Bill). It was conceived as a voluntary program that offered agricultural landowners annual rental payments and cost-share assistance for 10 to 15 years. Primary purposes of the CRP were to control commodity supply and reduce long-term soil erosion. The federal government supplied annual rental payments to participating landowners at the land's going rental rate and helped finance certain conservation practices. The 1985 Farm Bill evolved into a multipurpose conservation program through 1990 and 1996 amendments (McKenzie 1997). Amendments in 1996 created the Environmental Benefits Index (EBI) to quantify and rank management practices proposed for lands being considered for enrollment or re-enrollment. Scores were based on the expected benefit to wildlife habitat, soil resources, water quality, and other resource concerns (Farm Service Agency 1997).

Landowners enrolled in the CRP could implement 1 or more of 13 vegetative cover and management practices. Common conservation practices selected included planting of wildlife-beneficial grasses and legumes (CP1), establishing permanent native grasses (CP2), tree planting (CP3), establishing permanent wildlife habitat (CP4), and managing established trees and vegetative cover (CP11) (Issacs and Howell 1988).

The principal conservation practice chosen by landowners in the Southeast was tree planting (CP3). By 1 January 1997, southeastern landowners had enrolled 830,202 ha of land into a tree conservation practice. Tree plantings represented 56.8% of the total CRP enrollment in the Southeast and accounted for 87.3% of all CRP planting nationwide. The 3 southeastern states with the highest percentages of CRP land planted in trees were Georgia (91.3%), Florida (90.5%), and South Carolina (78.9%) (Farm Service Agency 1997). Beginning in 1995, 10-year CRP contracts began to expire. Financially, landowners would be well-served to allow trees planted under the CRP, CP3 category to continue to grow to merchantable size (Dangerfield et al. 1995). In addition to the future commercial value of the timber, a landowner who re-enrolled his tree plantings in the CRP in a CP11 category would continue to receive annual rental payments from the federal government. However, due to the use of the EBI since 1996, landowners desiring to re-enroll their tree plantings would increase their score and their chances of enrollment by thinning or creating openings in their plantings to improve wildlife habitat (Burger 2000).

The effects in the Southeast of retiring thousands of hectares of marginal, cropped land to CRP practices impacted land management on at least 2 levels. On a regional and landscape level, forest acreage in the Southeast has remained relatively stable over the last decade but the composition and quality of the forest have changed, resulting in displacement of diverse hardwoods and small crop fields by expanding pine stands (Helinski 2000). On a patch level, most CP3 lands in the Southeast were planted in loblolly pine at densities of about 1,793 trees/ha. Grassland and early successional bird species typically increase during the first few years after planting pines on agricultural land (Darden et al. 1990). After a few years, the grassland and early successional bird species give way to shrub-successional species, which peak in abundance and richness within 10 years of pine establishment (Burger 2000). The changes in wildlife species that use pine plantings mirror the changes in vegetation within a plantation. Canopy closure within pine plantings occurs after 8-10 years (Johnson et al. 1974, Felix et al. 1986, Melchoirs 1991, Allen 1994). Monotypic pine plantings provide few benefits to wildlife once the canopy closes and mid- and understory vegetation is shaded out (Johnson et al. 1974, Allen 1994). Early successional bird species, such as the prairie warbler (*Dendroica discolor*) and the northern bobwhite (*Colinus virginianus*), are of concern in the Southeast due to declining numbers (McKenzie and Riley 1995, Sauer et al. 1999, Burger 2000) and these older pine plantings are of little benefit to them.

Pine plantings that are not managed intentionally for wildlife, in addition to timber products, appear to offer few lasting benefits to wildlife. With periodic management treatments, however, most plantations can provide a greater diversity of habitat conditions (Allen et al. 1996). Management of CRP pine plantings ideally should benefit wildlife, not jeopardize the CRP status, and not significantly lower the economic return of the timber. Thinning pine stands and/or creating gaps in stands are methods that may meet these criteria. Precommercial thinning in pine plantings is a common practice and is encouraged under the current Farm Bill. Thinning pine plantings is an accepted practice for improving wildlife habitat because it opens the canopy and promotes growth of herbaceous and shrubby vegetation (Cushwa et al. 1969, Johnson et al. 1974, Conroy et al. 1982).

Benefits to various wildlife species from CRP plantings (primarily CP1 and CP2) have been documented by the U.S. Fish and Wildlife Service (Farm Service Agency 1997). Multiple studies have estimated the effect of the CRP on bird populations in the midwestern grasslands (Burger et al. 1990, Hayes and Farmer 1990, Stauffer et al. 1990, Johnson and Schwartz 1993, Reynolds et al. 1994, Millenbah et al. 1996, Best et al. 1998). Indeed, Ryan et al. (1998) reviewed literature to assess the impact of CRP on bird populations in the central USA and found that more than 90 species used CRP habitat. However, the response of avian species, particularly songbirds (passerines), to CRP pine plantings converted from agricultural lands and the subsequent thinning of CRP pine plantings, has received little quantitative attention (Burger 2000).

Thus, a need was recognized to determine the responses of the avian community, especially songbirds, to thinning and creating openings in CRP pine plantings to create habitat suitable for several wildlife species. A few studies examined the avian community in modified CRP pine stands (Burger 2000, Ellenberger 2000, Schaefbauer 2000), but none had examined the relationship between the avian community and the landscape around CRP pine plantings. We hypothesized that populations of resident and migratory birds would be affected by the within-stand modification of CRP pines and by the interspersion of habitats across the agricultural/silvicultural landscape. To assess the influence of the landscape structure and composition, as well as modifications to CRP pine plantings, on the avian community during the spring breeding period, we analyzed the influence of large-scale habitat elements (Penhollow and Stauffer 2000) on bird community richness and abundance. Our goal was to develop quantitative models for avian richness, avian abundance, and species abundance, based on landscape measurements and CRP sanctioned modifications.

METHODS

Study Area

Research was initiated in the Lower Coastal Plain physiographic region of South Carolina and the Upper Coastal Plain physiographic region of Georgia during Spring 1998. In South Carolina, 7 pine plantings (i.e., study sites) were selected in

Williamsburg (5 sites) and Orangeburg (2 sites) Counties. Pine plantings ranged in size from 15 to 32 ha. The shortest distance between any 2 pine plantings was 0.6 km and the greatest distance between any 2 pine plantings was 46.9 km. Plantings in Williamsburg County were in non-industrial private ownership, and those in Orangeburg County were on Westvaco (Westvaco/Meade) Corporation's Walworth Plantation. All pine plantings in South Carolina were agricultural fields before being planted to loblolly pine, and pine were of similar age. Plantings in Williamsburg County were enrolled in the CRP as CP3 pine plantings, whereas plantings in Orange County mimicked CRP planting and enrollment requirements. Landscapes surrounding the pine plantings were primarily comprised of fallow fields, agricultural fields, residential areas, and pine plantings, all interspersed within an upland and bottomland hardwood matrix.

In Georgia, 6 pine plantings were located in Burke County on Di-Lane Plantation Wildlife Management Area (WMA) (3 plantings) and the nearby Alexander WMA (3 plantings). Georgia pine plantings ranged in size from 13 to 27 ha; the shortest distance between any 2 pine plantings was 0.2 km and the greatest distance between any 2 plantations was 20.5 km. Di-Lane Plantation WMA was a 3,278-ha tract on which 286 ha were enrolled in the CRP as CP3 loblolly pine plantings in 1986. The U.S. Army Corps of Engineers purchased the WMA in 1992 as mitigation for lands flooded by Lake Russell and the Georgia Department of Natural Resources (DNR) began managing the property primarily for northern bobwhite. Alexander WMA was a 555-ha tract that was privately owned and planted primarily in row crops or used as pasture. In 1988, 380 ha of cropland were planted in loblolly pines following the CRP planting guidelines (1,793 trees/ha). The property was unmanaged after 1988 and was acquired by the Georgia

DNR in November 1997. Landscapes surrounding the pine plantings in Georgia were comprised of fallow fields, agricultural fields, residential areas, commercial hardwood operations (pecan [*Carya illinoensis*] orchards), and pine plantings, all interspersed within an upland and bottomland hardwood matrix.

Overall, pine plantings selected for investigation represented planting densities and available management practices common to CRP pine plantings located in the Upper and Lower Coastal Plain of the southeastern U.S. The greatest distance between Georgia and South Carolina pine plantings was approximately 221.5 km. Ages of the pine plantings ranged from 8–12 years at the initiation of this study, and were similar in growth and biological development (i.e., succession; C. G. White, University of Georgia, personal observation). All pine plantings were either enrolled in the CRP or mimicked CRP planting and enrollment requirements, and hereafter will be referred to as CRP pine plantings. Further, the landscapes surrounding the pine plantings were similar in land use patterns, although some variation occurred.

Field

Treatments.— Recommendations of the NRCS for already-established pine plantings to be re-enrolled in the CRP during 1997, were used as treatments, and these included: 1) thinning to $\leq$741 trees/ha (row thin), 2) creating openings in 20% of a stand's area and thinning to $\leq$741 trees/ha (open and row thin), and 3) no mechanical modification to pine plantings (control). Treatments were assigned randomly to pine plantings within Di-Lane Plantation WMA and Alexander WMA. Each treatment was replicated twice. Due to preferences among landowners and the restricted number of potential sites, treatments were not randomly assigned to pine plantings in South

Carolina. Each treatment was replicated twice, except the control which was replicated 3 times.

Openings created in the Georgia pine plantings were equidistant, 22-m wide strips running from edge to edge of plantings. Area of the openings ranged from 0.3–0.5 ha at Di-Lane Plantation WMA, to 0.9–1.5 ha at Alexander WMA. In South Carolina, openings were square-shaped and in the interior of plantations. Areas of openings ranged from 1.5–1.8 ha. Application of treatments (thinning) extended from March to June 1998 due to excessive precipitation.

Birds.—Breeding bird surveys were conducted from $25-m fixed-radius point count stations established at 50-m intervals (Georgia) or 100-m intervals (South Carolina) along transects. Location of the initial transect through each pine planting was a randomly selected point near the corner of the planting. Subsequent transects in the pine planting were parallel to and 150-m from the preceding transect. Three surveys of each pine planting were conducted each season (April – July 1998 and 1999) in satisfactory weather conditions, after sunrise until 1030 hr EST, and order of transect visits was rotated (Ellenberger 2000, Schaefbauer 2000). Each count from a station lasted 4 – 5 min. An individual bird detected at >1 station was recorded only once during a survey.

Habitat.—The pine plantings and surrounding habitat types located in Georgia and South Carolina were digitized at a scale ≥1:3,000 m, referencing U.S. Geological Survey 1993–1995 Digital Orthophoto Quarter Quadrangles (DOQQ) with a root mean square error (RMSE) of ≤1.6 m in ESRI™ ArcView (Environmental Systems Research Institute 1999*b*). Researchers' knowledge of the area, 1999 low-level aerial photos (South Carolina), other remote imagery, and inspection of unfamiliar areas were used to correctly classify, modify, and update 1993–1995 landscape polygons to represent the 1999 landscape. Habitat types delineated included agricultural fields, closed-canopy planted pine, early successional, hardwoods, mature pine, open-canopy planted pine, and other (Table 2.1). Except residential areas within the "other" category the smallest mapping unit was 0.2 ha. Residential areas were digitized in mapping units <0.2 ha. The final Geographical Information System (GIS) database included all pine plantings and all habitat types within $250-m radius of each pine planting.

Analytical

Birds.—Due to variation in how distance data were recorded during point counts in the Georgia and South Carolina study areas (Ellenberger 2000, Schaefbauer 2000), we used only records of birds within the first 25 m of the center of each point count station. Counts of birds flying over the canopy and wide-ranging species (e.g., crows, birds of prey) were not included (Blake and Karr 1987). Only data from point count stations with $50% of their area (0.2 ha) in the pine planting were included in analyses. Data from April – July 1999 were analyzed to examine avian response to treatments 1 year after application.

A species abundance index (individuals/ha) for each pine planting was obtained by summing the number of individuals per species within each of 3 survey periods. The greatest number of individuals of a species from the 3 survey periods was used as the maximum number of individuals for that species. The total maximum number of all individuals was calculated by summing the maximum number of individuals per species and dividing by the standardized area sampled for each pine planting. Because pine plantings differed in both size and the number of point count stations we established in each, we standardized area sampled for abundance data by multiplying the area sampled per point count station (0.20 ha) by the total number of point count stations per pine planting.

A species richness index (maximum number of species detected during the 3 survey periods) for each pine planting was obtained from 11 randomly selected point count stations in each pine planting. Two pine plantings only had 11 point count stations established in them, hence, all 11 point count stations were used.

In addition, species detected in pine plantings were categorized by migratory strategy (Ellenberger 2000) and nesting guild (Schaefbauer 2000). Species in migratory strategies (Table 2.2) were categorized as resident or short-distance migrant species (SDM), or Neotropical migrant species (NTM). Species in nesting guilds (Table 2.3) were categorized as 1) cavity nesters, 2) ground nesters, 3) shrub nesters, or 4) tree nesters. We calculated an abundance index (individuals/ha) for each pine planting, for each migratory strategy and nesting guild.

Habitat.— We buffered each pine planting with a 250-m radius to evaluate the role habitat surrounding pine plantings may have had on bird assemblages and abundance. Buffered pine plantings were intersected with the habitat coverage using ArcView's Geoprocessing Wizard. Resulting polygons represented the pine planting and surrounding habitat within a 250-m radius (i.e., landscape). Total area within these landscapes ranged from 75 to 124 ha, with a mean of 96 ha (SD = 16 ha). No pine planting comprised >28% of the landscape, and only 2 landscapes overlapped (<18% and <12%). Polygons of the same habitat types adjacent to one another, including any open- or closed-canopy planted pine stand polygons adjacent to planted pine polygons, were merged into one polygon. Polygons were converted from shape files to coverages using ESRI™ Arc/Info (Environmental Systems Research Institute 1999*a*). FRAGSTATS*ARC (Pacific Meridian Resources 2000) integrity checks were used to identify overlapping polygons and missing attribute information. Errors detected were corrected in Arc/Info coverages. We generated class and landscape level metrics (McGarigal and Marks 1995) for each pine planting's landscape coverage using FRAGSTATS*ARC.

Data Analysis.—Six class and landscape level metrics produced for the landscape coverages were selected for potential entry into a stepwise multiple linear regression analysis (PROC REG; SAS Institute 1990, 1999) as predictor or effect variables. The 6 predictor variables chosen were: patch density (PD), patch richness density (PRD), interspersion and juxtaposition index (IJI), contrast-weighted edge density (CWED), percentage of the landscape composed of early successional habitat (ES_PLAND), and percentage of the landscape composed of hardwood (Hwd_PLAND; Table 2.4). Avian richness and abundance indices were the response variables. Models were also developed for each migratory strategy and nesting guild abundance. Metrics selected as predictor variables were chosen *a priori* to avoid redundancy among metrics, and based on perceived biological relevance to the dependent variables and their relevance to the objectives of this study (Penhollow and Stauffer 2000). Correlation and multicollinearity diagnostics were performed on the 6 predictor variables selected and 1 variable (CWED) was subsequently removed from further analysis.

Four categorical non-landscape associated predictor variables were considered for the stepwise multiple linear regression analyses, in addition to the landscape and class level metrics. These variables included treatment level, corresponding to control (Treat1), row thin (Treat2), and open and row thin (Treat3), and Study area location, corresponding to Georgia and South Carolina (Study; Table 2.4). In the stepwise procedures, significance levels were set at 0.25 for a variable to enter and 0.15 for a variable to stay in the model.

Diagnostic evaluation of migratory strategy and nesting guild abundance models indicated that 3 (cavity nesters, shrub nesters, NTM) models were influenced by a single pine planting (i.e., data point). Removing the pine planting, potentially acting as a statistical outlier, resulted in very little change. The initial variables, and the signs of the coefficients, selected by stepwise procedures stayed the same in 2 models (shrub nesters, NTM). Initial variables, and signs of the coefficients, selected by stepwise procedures were maintained in the other model (cavity nesters), but 2 additional variables were added to the models with removal of a data point. In addition, all 3 models had a new data point acting in an influential manner. Influential points for all 3 models were open and row thin pine plantings at the South Carolina study area.

All 3 models that were diagnosed with influential points received no loss of initial variables selected when the influential pine planting was removed from analyses. Dropping the influential pine planting in the cavity nesters and NTM models resulted in lower *P*-values and higher adjusted coefficient of multiple determination (R^2 adj.) values. These results indicated that models with a tighter fit were achieved, but also that the models were overfitted (see Montgomery and Peck [1992] for a discussion of outlier and influential points). Dropping the influential pine planting in the shrub nesters model resulted in a higher *P*-value and slightly lower R^2 adj. value, but the change did not affect the significance of the model and had a minor change on the R^2 adj. value. Therefore, we report and subsequently discuss only the variables and models initially selected by the stepwise procedures when all pine plantings were included in the data analyses. Likely these are more representative of the results one would achieve with a larger sample size, and represent more of the variation that would be encountered throughout the South Atlantic coastal plain.

Models can be to checked to see if they are overfit by comparing the root mean square press (RMSP) to the root mean square error (RMSE). A model with a RMSP that is 1.3 – 2.0 times as large as the RMSE is typically a candidate for an overfit model (Jaxk Reeves, University of Georgia, personal communication). We note that the RMSP of the ground nesters model was 1.5 times as large as the RMSE, had a proportionally large number of variables selected (5) compared to the sample size (13), and may have been overfit.

RESULTS

Summary Statistics.—The 4 most abundant species recorded at the South Carolina study area, in descending order, were northern cardinal (*Cardinalis cardinalis*), pine warbler (*Dendroica pinus*), summer tanager (*Piranga rubra*), and Carolina chickadee (*Poecile carolinensis*) and Carolina wren (*Thryothorus ludovicianus*) (tied). The 4 most abundant species recorded at the Georgia study area, in descending order, were Carolina chickadee, tufted titmouse (*Baeolophus bicolor*), northern cardinal, and pine warbler. In both study areas, the 4 most abundant species recorded, in descending order, were northern cardinal, Carolina chickadee, pine warbler, and tufted titmouse. Thirty-one species were recorded at the South Carolina study area and 24 were recorded at the

Georgia study area. Collectively, 34 species were recorded in or on the edge of managed pine plantings.

Mean bird abundance for all pine plantings was 7.2 birds/ha (SD = 1.2 birds/ha). Mean bird abundance of the South Carolina study area was 7.7 birds/ha (SD = 1.3 birds/ha), and that of the Georgia study area was 6.7 birds/ha (SD = 1.0 birds/ha). A total of 51.8 ha of managed pine plantings was sampled by point counts: 24 ha in South Carolina and 27.8 ha in Georgia. Species richness for all pine plantings was 9.8 species/pine planting (SD = 2.3 species/pine planting). Species richness of the South Carolina study area was 9.6 species/ pine planting (SD = 3.0 species/ pine planting), and that of the Georgia study area was 10.0 species/ pine planting (SD = 1.2 species/ pine planting).

Models.— The 5 predictor variables used in our regression analyses included: percentage of landscape composed of early successional habitat (ES_PLAND), percentage of landscape composed of hardwoods (Hwd_PLAND), patch density (PD), patch richness density (PRD), and interspersion and juxtaposition index (IJI) (Table 2.4). Only PD was selected by stepwise procedures to model avian abundance in pine plantings (R^2 adj. = 0.32, P = 0.025; Table 2.5). Avian abundance and PD were positively related. Stepwise procedures selected ES_PLAND, Hwd_PLAND, and IJI as variables that predicted avian richness in the 13 pine plantings (R^2 adj. = 0.53, P = 0.019; Table 2.5). All 3 variables were positively related to avian richness.

We attempted to develop regression models using abundance/ha, and the migratory strategies and nesting guilds. A multiple linear regression model, given our predictor variables, was not appropriate for the SDM migratory strategy. The NTM migratory strategy model consisted solely of a metric variable.

Predictor variables included in the 4 nesting guild models consisted of a mixture of categorical and metric variables (Table 2.6). Categorical variables included in models were Study (cavity nesters and ground nesters), Treat2 (shrub nesters), and Treat3 (cavity nesters, ground nesters, and tree nesters). The metric variable occurring in the greatest number of migratory strategy and nesting guild models was PD (NTM, ground nesters, and tree nesters). The variable IJI occurred in 2 nesting guild models (ground nesters and shrub nesters). The variables ES_PLAND (ground nesters), Hwd_PLAND (cavity nesters), and PRD (ground nesters) each occurred in only 1 nesting guild model. The R^2 adj. values of the migratory strategy and nesting guild models ranged from 0.324 (tree nesters) to 0.966 (ground nesters), and models developed were significant ($P = 0.057$, tree nesters) to strongly significant ($P < 0.001$, ground nesters).

DISCUSSION

Prediction of abundance and richness are not necessarily indicators of reproductive success or habitat quality (Van Horne 1983, Pulliam 1988, Penhollow and Stauffer 2000). Due to resource limitations and data collection procedures, we were unable to obtain desired demographic data. However, Penhollow and Stauffer (2000) noted that if a given habitat element was ‘good’ (i.e., quality habitat) for a species, then individual species abundance or diversity would increase with that particular habitat element.

Avian abundance increased with patch density (PD). Patch density is a fundamental aspect of landscape structure but limited in interpretation, meaning it implies no indication of diversity or evenness of the landscape. It indicates degree of fragmentation of the landscape when coupled with patch type. When interpreted over the entire landscape mosaic it can serve as a good spatial heterogeneity index (McGarigal and Mark 1995). Our quantitative model predicted an increase in abundance/ha as the spatial heterogeneity of patch density increased within the landscape surrounding the pine plantings. As mentioned, this does not imply an increase in patch diversity but one would expect that the greater the patch heterogeneity, the greater the increase in patch diversity and the increase in edge encounters in the landscape. Such a mosaic of habitat patches would result in an increased likelihood of providing for a bird's needs (e.g., food, shelter, water) within a smaller area. Because we limited ourselves to 7 habitat types and these 7 habitat types surrounded most of the pine planting landscapes, the diversity of patches may not have been expressed due to our limits on habitat type delineation.

Avian species richness increased with the percentage of early successional habitat (ES_PLAND), percentage of hardwood (Hwd_PLAND), and interspersion and juxtaposition (IJI) of habitat types in the landscape around pine plantings. The IJI metric at the landscape level measures the amount of interspersion of patch types and is not necessarily affected by patch size, contiguity, or dispersion of patches. A higher IJI value would result from landscapes in which patch types were equally adjacent to each other (well interspersed). Conversely, a lower IJI value would result from landscapes in which patch type adjacencies were distributed disproportionately (McGarigal and Marks 1995). Intuitively, it makes sense there would be an increase in avian richness when the percentage of early successional and hardwood habitat increased in the landscape, as well as an increase in the interspersion of available habitat types. Because hardwood and early successional habitats can support a wide array of bird species, the landscape around a pine planting dominated by these habitat types with a variety of other habitat types intermingled and well interspersed would support a great variety of bird species. Others (Johnston and Odum 1956, MacArthur and MacArthur 1961, Johnson 1975) have discussed positive relationships between measures of avian diversity and measures of habitat diversity.

An inability to predict SDM abundances with the treatment level, study area, or landscape structure surrounding the pine plantings could be a result of multiple factors. Some factors may be the lack of proper predictor variables being selected by the researchers for entry into the stepwise procedures, a low sample size, and treatment replications.

We were able to predict abundance/ha of NTM with one of the *a priori* variables. The variable PD was positively associated with an increase in NTM abundance. Thus it appeared that the species of NTM we detected in our study areas increased in abundance as the density and possibly the variety of habitat patches increased.

The abundance of cavity nesters, ground nesters, and tree nesters within pine plantings were partially predicted by the study location (negative sign indicated greater abundance/ha in Georgia). This relationship could be compounded by several biological (e.g., weather, treatment responses) and regional factors (e.g., upper coastal versus lower coastal plain). Further, the South Carolina Treat3 differed as to where the openings were placed (interior) and the shape (square) of the openings compared to Georgia Treat3 pine plantings (edge to edge openings, linear shape). Although point count procedures were similar and indices were standardized, we cannot discount that differences in researchers' field bias at point count stations may have affected results. We have wisely chosen not to guestimate the relationship between study location and nesting guild abundance based on our limited data.

Abundance of cavity nesters was partially predicted by a negative association with the percentage of hardwood in the landscape and the positive association of open and row thin treatment (Treat3). This appears counterintuitive because one would assume that hardwoods would provide more nesting opportunities in the landscape and that an open and row thin treatment would decrease nesting opportunities in the pine plantings. Our modeling effort also predicted an increase in cavity nesters in the Georgia study area as compared to the South Carolina study area. The greatest abundance of cavity nesters was in open and row thin treatments in both Georgia and South Carolina study areas.

In the Georgia study area, Schaefbauer (2000) detected significantly more individuals of the cavity guild in thin row treatments after mechanical treatment. Detections of this guild may have been in response to increased foraging opportunities resulting from increased visibility of prey, or an increase in insects due to logging disturbance. It is also possible that the treatments did attract more birds to the pine plantings. These explanations by Schaefbauer (2000) are reasonable to explain why open and row thin treatments may attract cavity guild species shortly after mechanical treatment, but they do not explain why the abundance of the cavity guild species in pine plantings would be negatively associated with the percentage of hardwoods in the landscape around pine plantings. Indeed, if cavity guild species were using pine plantings for foraging opportunities only, then we would expect more cavity guild members in pine stands with more hardwood in the surrounding landscape, unless cavity guild members are only required to forage in pine plantings in areas where hardwoods are not adequate in size.

The percentage of early successional habitat and patch density in the landscape, and open and row thin treatment of the pine plantings positively influenced ground nesters. Patch richness density (PRD) and interspersion and juxtaposition of patches negatively influenced ground nesters. Open and row thin treatments were designed to open the canopy, increase light, and subsequently increase vegetative diversity and structure. Burger (2000), citing his unpublished data, reported a greater diversity of birds in pine plantings 1 year after thinning compared to 3 other management regimes (thin/burn, thin/Arsenal herbicide, thin/Arsenal herbicide/burn). He did not investigate open and row thin plantations, but our analyses found this treatment to be predictive at our sites. It is not surprising then that the amount of early successional habitat in the landscape and a treatment that would increase early successional habitat within the pine plantings would be highly predictive of ground nesters.

Patch richness density standardizes richness to a per area basis and allowed comparisons among the landscapes surrounding our pine plantings. A high PRD would indicate a diverse mosaic of patch diversity and a low PRD would indicate little patch diversity. A low IJI index would also indicate a lack of interspersion. Thus ground nesters appear to increase in abundance in pine plantings that are patchy within and without, but the patches are mostly in the form of early successional habitat. A smorgasbord of habitat types evenly dispersed across the landscape would not be as beneficial as a patchy distribution of early successional habitat. The negative relationship of songbirds to patch diversity evenly dispersed in the landscape may be a response of ground nesters to avoid predators. For example, Dijak and Thompson (2000) documented that opossums (*Didelphis virginiana*) were more abundant in heterogeneous landscapes with widely spaced patches of forest and high densities of riparian habitat. Dijak and Thompson's (2000) findings also suggested that only some types of edge or fragmentation affect predator activity and numbers.

Shrub nesters were partially predicted by the presence of a thin row treatment (Treat2), resulting in a negative response towards a treatment designed to open the canopy, increase light, and subsequently increase vegetative diversity and structure. However, our data were from 1 year post treatment, so immediate benefit to shrub nesting birds would be minimal or negative due to the potential reduction of existing shrubs within pine plantings. Schaefbauer (2000) noted that shrub species in the Georgia study area were concentrated in *Rubus* thickets within or on the edge of the pine plantings, and that many of these thickets were destroyed during thinning. In slash pine (*Pinus elliottii*), species richness and diversity were greater in years 2 to 6 than in year 1 after pine planting (Johnson and Landers 1982). We expect that with time and maintenance of the canopy opening, that row thinned pine plantings would develop a shrub layer that would benefit shrub nesters. The interspersion and juxtaposition of habitat types around pine plantings positively benefited shrub nesters, possibly offsetting initial loss of shrub layers within pine planting by offering a variety of habitat types evenly interspersed throughout the landscape.

Tree nesters were positively related to patch density in the landscape surrounding pine plantings. A high patch density would indicate an increase in edge encounters in the landscape and some diversity across the landscape. Increase in edges and patches potentially would provide a variety of tree species, age of trees, and height of trees. Such a combination repeated over the landscape surrounding a pine planting would provide for a bird's needs (e.g., food, shelter, water).

Abundance of NTM, ground nesters, and tree nesters responded positively to patch density. Farms throughout the Southeast have been declining in numbers and increasing in size, resulting in the consolidation of many small farms into one large farm with less interspersion of field borders, etc. (Helinski 2000). Yet we detected that both migratory strategy and nesting guilds, as well as overall population abundance estimates, responded positively to spatial heterogeneity. Fragmentation for some species is detrimental (i.e., forest core species) but fragmentation in agricultural and silvicultural areas may be beneficial to some early successional and shrub successional songbird species. In our modeling efforts, ground nesters responded positively to the percentage of early successional habitat in the landscape. Our modeling of nesting guild abundance often resulted in a mixture of within stand treatment effects and landscape effects.

Important biological information was provided when stepwise regression chose class and landscape metrics over the treatment level and study area. This indicated that in our study the variables having the greatest effect on avian abundance and richness in pine plantings were not mechanical treatment or study area, but were landscape structure surrounding the pine plantings. On the other hand, the variables exerting the greatest effect on nesting guild abundance were a combination of mechanical treatment, study area, and landscape metrics. This indicated that within the avian community, specific nesting guilds are influenced by both the structure within pine plantings and without pine plantings. In some cases, the landscape surrounding the pine plantings may be more predictive of species relationship with the pine planting than the within pine planting changes we created.

MANAGEMENT IMPLICATIONS

Avian community management in CRP pine plantings requires both within patch and among patch diversity (i.e., diversity within the landscape). Landscape around pine plantings will have a greater effect on bird abundance, richness, and NTMs found within pine plantings, than will a mechanical treatment 1 year post treatment. However, mechanical treatment and study area, as well as the landscape, will predict abundance of nesting guilds. With > 48,963 ha in Georgia and 42,053 ha in South Carolina (Burger 2000) of CP11 CRP pine plantings, an enormous opportunity exists to use thinning and openings to create within patch diversity and subsequently, diversity in the landscape. Thinning and creating openings in CRP pine plantings should help increase the abundance of ground nesters. Patch density around pines was a predictor of overall abundance and abundance of nesting guilds. Ground nesters responded positively to the amount of early successional habitat available in the surrounding habitat. Avian species will respond to different cues within patches, at the patch level, and at the landscape level. Birds sensitive to patch size may do better in square, larger openings such as were created in the South Carolina study area. Understanding which wildlife species a manager wants to benefit, by modification to pine plantings, is crucial when implementing thins, creating openings, or modifying habitat surrounding CRP pine plantings. In general, modifications within CRP pine stands will result in greater avian (early successional) abundance, and modifications within CRP pine stand embedded in a diverse and patchy mosaic will result in increased abundance and richness of early successional bird species. Due to the 1996 changes to the CRP, if landowners wished to profit by re-enrolling pine plantings into the program, thinning and openings should promote increased diversity of habitat and subsequently, greater diversity and abundance of bird species.

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Table 2.1. Habitat types and their composition, delineated for the classification and digitizing of study areas in Georgia and South Carolina, USA.

Habitat type	Composition
Agricultural fields	Cultivated fields, pecan orchards, <1 year old clearcuts, pasture, hay fields, mowed yards, exposed soils
Closed-canopy planted pine	Managed planted pine stands at canopy closure (typically >5 years old)
Early successional	Fallow areas, 1-4 year old clearcuts, rights-of way, young hardwood plantations, natural young pines and hardwoods (typically #5 years)
Hardwoods	Stand composed of $50% bottomland or upland hardwoods >5 years old
Mature pine	Stand composed of >50% pines >20 years old, or patches ≥0.8 ha in size in large forested hardwood tracts (>12 ha)
Open-canopy planted pine	Thinned, managed pine plantings, <5 year old planted pine, planted long leaf pine (*Pinus palustris*)
Other	Residential areas (houses or large buildings), roads (major paved or unpaved road with ≥2 lanes), and water (permanent or semi-permanent open ponds >0.2 ha)

Table 2.2. Songbird species detected in pine plantings during 1999 in Georgia and South Carolina, USA, and grouped by migratory strategy.

Migratory strategy	Species
SDM (Short distance migrant)	Carolina wren (*Thryothorus ludovicianus*), eastern bluebird *(Sialia sialis*), Carolina chickadee (*Poecile carolinensis*), downy woodpecker (*Picoides pubescens*), tufted titmouse (*Baeolophus bicolor*), pileated woodpecker (*Dryocopus pileatus*), red-bellied woodpecker (*Melanerpes carolinus*), field sparrow (*Spizella pusilla*), eastern towhee (*Pipilo erythrophthalmus*), red-winged blackbird (*Agelaius phoeniceus*), northern mockingbird (*Mimus polyglottos*), common yellowthroat (*Geothlypis trichas*), brown-headed cowbird (*Molothrus ater*), brown thrasher (*Toxostoma rufum*), gray catbird (*Dumetella carolinensis*), blue jay (*Cyanocitta cristata*), mourning dove (*Zenaida macroura*), northern cardinal (*Cardinalis cardinalis*), pine warbler (*Dendroica pinus*), red-eyed vireo (*Vireo olivaceus*)
NTM (Neotropical migrant)	Great crested flycatcher (*Myiarchus crinitus),* indigo bunting (*Passerina cyanea*), Kentucky warbler (*Oporornis formosus*), blue grosbeak (*Guiraca caerulea*), painted bunting (*Passerina ciris*), wood thrush (*Hylocichla mustelina*) , yellow-breasted chat *(Icteria virens*), eastern kingbird (*Tyrannus tyrannus*), eastern wood-pewee (*Contopus virens*), blue-gray gnatcatcher (*Polioptila caerulea*), acadian flycatcher (*Empidonax virescens*), summer tanager (*Piranga rubra*), northern parula (*Parula americana*), ruby-throated hummingbird (*Archilochus colubris*)

Table 2.3. Songbird species detected in pine plantings during 1999 in Georgia and South Carolina, USA, and grouped by nesting guilds.

Nesting guild	Species
Cavity	Carolina wren (*Thryothorus ludovicianus*), eastern bluebird *(Sialia sialis*), great crested flycatcher (*Myiarchus crinitus*), Carolina chickadee (*Poecile carolinensis*), downy woodpecker (*Picoides pubescens*), tufted titmouse (*Baeolophus bicolor*), pileated woodpecker (*Dryocopus pileatus*), red-bellied woodpecker (*Melanerpes carolinus*)
Ground	Field sparrow (*Spizella pusilla*), eastern towhee (*Pipilo erythrophthalmus*), indigo bunting (*Passerina cyanea*), red-winged blackbird (*Agelaius phoeniceus*), Kentucky warbler (*Oporornis formosus*)
Shrub	Northern mockingbird (*Mimus polyglottos*), common yellowthroat (*Geothlypis trichas*), brown-headed cowbird (*Molothrus ater*), blue grosbeak (*Guiraca caerulea*), brown thrasher (*Toxostoma rufum*), gray catbird (*Dumetella carolinensis*), painted bunting (*Passerina ciris*), wood thrush (*Hylocichla mustelina*), yellow-breasted chat *(Icteria virens*)
Tree	Eastern kingbird (*Tyrannus tyrannus*), eastern wood-pewee (*Contopus virens*), blue-gray gnatcatcher (*Polioptila caerulea*), acadian flycatcher (*Empidonax virescens*), blue jay (*Cyanocitta cristata*), summer tanager (*Piranga rubra*), mourning dove (*Zenaida macroura*), northern cardinal (*Cardinalis cardinalis*), northern parula (*Parula americana*), pine warbler (*Dendroica pinus*), red-eyed vireo (*Vireo olivaceus*), ruby-throated hummingbird (*Archilochus colubris*)

Table 2.4. Class and landscape metrics[a], and categorical variables, used as predictor variables in the development of multiple linear regression models of bird species richness and abundance responses to landscape characteristics adjacent to pine plantings during 1999 in Georgia and South Carolina, USA.

Mnemonic code	Units	Description
ES_PLAND	%	Percentage of landscape composed of early successional habitat
Hwd_PLAND	%	Percentage of landscape composed of hardwood habitat
PD	no./100 ha	Patch density; number of habitat patches per unit area
CWED	m/ha	Contrast-weighted edge density; combined edge density and edge contrast and standardized metric to per unit area
PRD	no./100 ha	Patch richness density; number of patch types per unit area
IJI	%	Interspersion and juxtaposition index; measures the level of patch interspersion relative to the maximum possible
Treat1	binary	Pine planting in landscape that received no mechanical treatment (control); used as baseline
Treat2	binary	Pine planting in landscape that received a row thin treatment
Treat3	binary	Pine planting in landscape that received an open and row thin treatment

Table 2.4. Continued

Mnemonic code	Units	Description
Study	binary	Pine planting located in Georgia or South Carolina; Georgia used as baseline

[a] See McGarigal and Marks (1995) for formulas and more detailed descriptions of habitat measures.

Table 2.5. Model coefficients and standard errors (SE), adjusted coefficient of multiple determination (R^2 adj.), and significance values resulting from stepwise multiple linear regression of avian species richness and abundance in 1999 at pine plantings located in Georgia and South Carolina, USA. Sample size for all stepwise procedures was 13 pine plantings.

		Predictor variable[a]					
Response	Intercept	PD	ES_PLAND	Hwd_PLAND	IJI	R^2 adj.	P[b]
Abundance	4.985	0.077				0.324	0.025
	(0.910)	(0.030)					
Richness	-1.430		0.205	0.098	0.069	0.534	0.019
	(3.291)		(0.062)	(0.044)	(0.044)		

[a] PD = patch density, ES_PLAND = percentage of early successional habitat in the landscape, Hwd_PLAND = percentage of hardwood in the landscape, IJI = interspersion and juxtaposition index; predictor variables not selected in stepwise regression models are not shown.

[b] *P*-value for full model

Table 2.6. Model coefficients and standard errors (SE), adjusted coefficient of multiple determination (R^2 adj.), and significance values resulting from stepwise multiple linear regression of migratory strategy and nesting guild abundance in 1999 at pine plantings located in Georgia and South Carolina, USA. Sample size for all stepwise procedures was 13 pine plantings.

		Predictor variable[a]									
Migratory strategy or nesting guild	Intercept	ES_PLAND	Hwd_PLAND	PD	PRD	IJI	Treat2	Treat3	Study	R^2 adj.	P[b]
SDM[c]											
NTM	-0.380			0.081						0.394	0.013
	(0.840)			(0.027)							
Cavity nesters	3.344		-0.022					0.898	-1.058	0.509	0.0241
	(0.440)		(0.012)					(0.368)	(0.346)		
Ground nesters	4.489	0.012		0.039	-0.296	-0.042		0.320		0.966	<0.001
	(0.358)	(0.004)		(0.005)	(0.031)	(0.003)		(0.075)			
Shrub nesters	-1.731					0.027	-0.736		0.893	0.641	0.006
	(0.785)					(0.010)	(0.258)		(0.229)		

Table 2.6. Continued.

	Predictor variable[a]										
Migratory strategy or nesting guild	Intercept	ES_PLAND	Hwd_PLAND	PD	PRD	IJI	Treat2	Treat3	Study	R^2 adj.	P^b
Tree nesters	-1.320			0.554					1.230	0.324	0.057
	(1.721)			(0.248)					(0.797)		

[a] ES_PLAND = percentage of early successional habitat in the landscape, Hwd_PLAND = percentage of hardwood in the landscape, PD = patch density, PRD = patch richness density, IJI = interspersion and juxtaposition index, Treat2 = row thin treatment, Treat3 = open and row thin treatment, Study = study area; predictor variables not selected in stepwise regression models are not shown.

[b] *P*-value for full model

[c] Stepwise procedure (SAS Institute 1999) did not result in any *a priori* chosen categorical, class and landscape metric variables being chosen at entry level = 0.25 and stay level = 0.15.

CHAPTER 3

EVALUATION OF THE LANDSCAPE SURROUNDING NORTHERN BOBWHITE NEST SITES: A MULTISCALE ANALYSIS[1]

[1]White, C. G., S. H. Schweitzer, I. B. Parnell, and L. A. Lewis. To be submitted to The Journal of Wildlife Management.

ABSTRACT: Implementation of the Conservation Reserve Program (CRP) and its conservation practices altered the interspersion of habitat cover and proportion of habitat cover available in landscapes of the Southeast. Studies have quantified the effect that changes to the landscape, as a result of the CRP, are having on northern bobwhite (*Colinus virginianus*), but little has been done to evaluate the relationship of the landscape structure and northern bobwhite nest locations. Further, the association of northern bobwhite nest locations and the landscape structure may be different among spatial scales. We used GIS and spatial analysis software to calculate class and landscape measurements around bobwhite nest sites. Our objective was to determine the components of landscape structure that were important in predicting nest site selection of bobwhite at different spatial scales. Patch density and open canopy planted pine were consistent predictor variables in modeling nest site selection in the landscape. Patch density could be increased in large monotypic stands of closed canopy planted pine stands by thinning rows of pines. Thinning and creating openings in CRP pine plantations should provide increased nesting opportunity for bobwhites.

INTRODUCTION

The interspersion of fallow fields, hardwood forest, pine plantations, and croplands found in the southeastern United States creates a landscape mosaic of habitat cover types. Since the inception of the CRP in 1985, >830,202 ha of farmland have been converted to tree plantations (mostly pine) in the Southeast (Farm Service Agency 1997). Allen (1993) reported that the establishment of pine plantations under the CRP might have eliminated thousands of acres of high-quality nesting, brood rearing, and foraging habitat in the Southeast. Little work has been done to evaluate the effects of the changing landscape mosaic on wildlife use and movements.

Within the changing landscape mosaic of the Southeast, northern bobwhite (hereafter, bobwhite) require nesting habitat, brood-rearing habitat, feeding areas, roosting areas, and appropriate escape cover to survive (Stoddard 1931, Rosene 1969, Schroeder 1985). Areas disturbed every 1-4 years may meet these life requirements (Rosene 1969, Melchiors 1991, Landers and Mueller 1992, Stewart et al. 1997, Thackston and Whitney 2001). Bobwhite, considered residents of several habitat types including open pine woodlands, woodland edge, shrubs, agricultural fields, pastures, rangeland and fallow fields (Carroll 1994:425), have been declining over much of their range (Brennan 1991, Church et al. 1993). Brennan (1991) noted that all available evidence points to one reason for bobwhite population decline: inferior bobwhite habitat. Brennan (1991) also noted that effective habitat management for bobwhite has been known for over half a century. Intensification of agriculture and silviculture has resulted in increased field sizes, monoculture plantings, and loss of diversity within agricultural (Langner 1985) and silvicultural dominated landscapes (Helinski 2000).

A few studies have evaluated the potential effects that the CRP has had on available habitat for bobwhite. Hays and Farmer (1990) found inconclusive evidence as to whether conversion of cropland to pine plantations resulted in a reduction of bobwhite winter food supply. Stauffer et al. (1990), using field data and simulation models, predicted that the quality of habitat for northern bobwhite would decline substantially as greater amounts of cropland are converted to CRP pine plantations. However, in their model Stauffer et al. (1990) did not evaluate the spatial relationships among the various habitats. Roseberry et al. (1994) used remote sensing, a geographical information system (GIS), and habitat modeling to assess the potential impact of the CRP on bobwhite habitat in southeastern Illinois where CRP land primarily consisted of introduced grasses and legumes. Roseberry et al. (1994) determined that contribution of CRP fields to habitat quality would depend on several things, including the juxtaposition of CRP fields with other habitat components. Burger et al. (1990), working in northern Missouri and in CRP fields established to grass and wildlife habitat conservation practices, determined that newly established fields provide roosting and brood rearing habitat, whereas older, better-established fields may provide nest habitat. The CRP in general has been considered highly beneficial for many wildlife species (Farm Service Agency 1997), but Ryan et al. (1998) reviewed the literature available to them and reported that little evidence existed to indicate a positive population response by bobwhites to the CRP.

Although Roseberry and Klimstra (1984) are repeatedly cited by various studies (e.g., Burger et al. 1990, Stauffer et al. 1990) for noting that habitat management for bobwhite should consider the juxtaposition and interspersion of habitat types, few studies have evaluated quantitatively the proper juxtaposition and interspersion of habitat for bobwhite needs. Roseberry and Sudkamp (1998) recently assessed the suitability of landscapes for bobwhite in Illinois by comparing landscape structure with indexes of bobwhite abundance. However, no work has been done to evaluate the relationship of bobwhites and landscape structure composed of agricultural and silvicultural practices in the Southeast.

Potentially, the CRP would result in a landscape of diverse habitats that could benefit bobwhite. The suitability of pine plantations and other habitat cover types for bobwhite use and benefit is affected by the spatial configuration of the land cover types (e.g., Burger et al. 1990, Stauffer et al. 1990). Allen et al. (1996) noted that spatial location of pine plantations can contribute to landscape-level habitat priorities addressing fragmentation and habitat composition. The increased ability of researchers to evaluate habitat type configuration, composition, and fragmentation on wildlife phenomena is evident by the subject matter of recent literature. The literature reveals a trend towards using geographic information systems (GIS), patch or landscape metrics, multivariate statistics, and modeling to examine relationships between wildlife locations and habitat types (Roseberry et al. 1994, Robinson et al. 1995, Ripple et al. 1997, Roseberry and Sudkamp 1998, Merrill et al. 1999, Miller et al. 2000, Penhollow and Stauffer 2000).

We used GIS and spatial analysis software to calculate class and landscape measurements around bobwhite nest sites. Because the association between bobwhite nest sites and the landscape structure may be different among spatial scales, we evaluated the relationship at 4 different distances. Logistic regression was used to spatially model (Miller et al. 2000) bobwhite nest sites' relationship to structure within the surrounding landscape. Our objectives were to determine components of landscape structure(s) important in predicting nest site selection of bobwhite and the spatial scale at which they were important.

STUDY AREA

This study was conducted on Di-Lane Plantation Wildlife Management Area (WMA) and Alexander WMA in Burke County, Georgia. Alexander WMA was a 555-ha tract in the Upper Coastal Plain physiographic region that, until 1988, was privately owned and planted primarily in row crops or used as pasture. In 1988, 380 ha of cropland were planted in loblolly pines (*Pinus taeda*) following CRP planting guidelines (1,793 trees/ha). The property was unmanaged after 1988 and was acquired by the Georgia Department of Natural Resources (GDNR) in November 1997. As of 1999, Alexander WMA included hardwoods (166 ha), fallow fields (9 ha), and planted pine (380). Movements of radio-marked quail beyond the Alexander WMA boundary increased the study area to 3,898 ha.

The Di-Lane Plantation WMA was a 3,278-ha tract. In 1986, 286 ha were enrolled in the CRP by the private landowner and planted in loblolly pine at 1,793 trees/ha. The U.S. Army Corps of Engineers purchased the land in 1992 as mitigation for lands flooded by Lake Russell at which time Georgia DNR began managing the property. Habitat types on Di-Lane included mixed pine-hardwoods (1,666 ha), fallow fields (849 ha), and planted pines (497 ha). Movement of radio-marked quail beyond the Di-Lane WMA boundary increased the study area to 11,918 ha.

Di-Lane Plantation and Alexander WMA were 16 km apart and were situated in a landscape of fallow fields, agricultural fields, residential areas, commercial hardwood operations (pecan [*Carya illinoenis*] orchards), and pine plantations, all interspersed among an upland and bottomland hardwood matrix. Movements of bobwhites ranged both on and off the WMAs. Study area boundaries around the WMAs were determined using arbitrary delineations such as roads and rights-of-way that were $800 m outside any recorded bobwhite location. When an unbroken habitat extended $1000 m beyond a recorded bobwhite location without an arbitrary boundary, a logical cut-off within the habitat type was used, such as a narrow area (i.e., where the habitat type was at its narrowest point). Delineated study areas were <6 km apart. Together the study area represented Burke County within the Upper Coastal Plain physiographic region of eastern Georgia. Hereafter, unless otherwise noted, reference to study area will collectively encompass both WMA study areas.

METHODS

Field

Nests.—From January – April, 1997–2000, we captured, banded, and radio-marked bobwhite (Lewis 1999; I.B. Parnell, University of Georgia, unpublished data). We located each bobwhite at least every other day at various times of the day, January - September. The homing technique (Mech 1983) and occasional flushing were used to determine approximate locations of birds. Nesting birds were located by inactive signals during otherwise normal active periods or repetition of daily locations. Locations of nests and radio-marked birds were recorded as Universal Transverse Mercator (UTM) coordinates using a GeoExplorer II hand-held global positioning system (GPS) receiver (Trimble Navigation Ltd., Sunnyvale, California). Research was conducted under the University of Georgia IACUC Protocol No. A960216C2.

Habitat.—The WMAs and surrounding habitat types were digitized at a scale ≥1:3,000 m, referencing U.S. Geological Survey 1993 Digital Orthophoto Quarter Quadrangles (DOQQ) with a root mean square error (RMSE) of ≤1.6 m in ArcView™ (Environmental Systems Research Institute 1999*b*). Researchers' knowledge of the area, remote imagery, and inspection of unfamiliar areas were used to correctly classify, modify, and update 1993 landscape polygons to represent 1997-2000 landscapes. Because bobwhite trapping did not start on Alexander WMA until 1998, habitat types were not delineated for this part of the study area in 1997. Habitat types delineated included agricultural fields, closed canopy pine, fallow fields, hardwoods, hedge rows, open canopy planted pine, and unavailable areas (residential housing and commercial buildings, major paved or unpaved roads with ≥2 lanes, and permanent or semi-permanent open ponds >0.2 ha; Table 3.1). In all habitat categories, except residential areas within the unavailable area category, the smallest mapping unit was 0.2 ha. Residential areas were digitized in mapping units <0.2 ha. The final GIS database included >15,816 ha of delineated habitat types. We verified the digital coverage while acquiring and recording bobwhite movements in the field. Average composition of the study area from 1997–2000 was 34.5% hardwood (SD = 0.4%), 27.0% agricultural fields (SD = 1.1%), 19.0% closed-canopy pine (SD = 1.5%), 11.9% fallow field (SD = 0.8%), 5.2% open-canopy planted pine (SD = 0.6%), 2.2% unavailable (SD = 0.1%), and 0.4% hedgerow (SD = 0.02%).

Agricultural fields consisted of row crops (primarily cotton, soybean, and peanuts; Morgan 2000), pecan orchards, pasture, hay fields, mowed areas, and soil exposed from a recent clearcut or in preparation to plant a crop. Fallow fields included fallow and idle fields, and clearcuts 1–4 years old. Rights-of-way (gas and power lines) were defined as fallow field except portions of a right-of-way that intersected an agricultural field, which were defined as agricultural field. We defined stands composed of >50% hardwood that were >5 years old as hardwood cover type, including clearcuts $5 years old. No distinction was made between bottomland and upland hardwoods, but most stands defined as hardwood were located along river bottoms and floodplains. Oak (*Quercus* spp.) and hickory (*Carya* spp.) dominated hardwood forests in the study area (Morgan 2000). Stands composed of >50% mature pines (>20 years old) were included in the closed-canopy pine cover type. In large forested tracts (>12 ha), composed of >50% hardwoods, mature pine was identified and digitized only if the mature pine area dominated an area ≥0.8 ha in size. Managed pine stands with closed canopy ($5 years old in our study area) were also defined as closed-canopy pine. Young managed planted pine stands were defined as open-canopy planted pine until 5 years old. Managed pine stands >5 years old and thinned were classified as open-canopy planted pine. Pine stands in our study area were primarily planted to loblolly pine. Hedgerows were defined as linear habitats that formed an edge with or through another habitat type(s) that was 8–15 m wide and longer than it was wide.

Analytical

Nests.—From 1997-2000, 39 nest attempts by bobwhites were located and geographical coordinates recorded. A nesting attempt was considered anything from the construction of a nest bowl to the successful hatch of a brood. Ten of 39 nesting attempts were re-nesting or double-clutching attempts (hereafter referred to as a re-nest). Twenty-nine nests were considered first time nest attempts. To avoid pseudo-replication (Hurlbert 1984) and lack of independence between >1 nest of radio-marked birds, and with no *a priori* justification to select >1 nest from the same hen, we randomly selected 1 nest from any bobwhite that had 2 or more nest attempts in 1 season. In one instance, the geographic coordinates of a re-nest attempt for a bobwhite were lost and the first nest attempt was selected as the nest representing this bobwhite by *de facto*. Hence, 29 nest sites were used in analyses.

Habitat.— Random points (n = 29) were generated using a uniform random distribution over the extent of the digitized study areas in proportion to the number of nests associated with each WMA using the Animal Movement extension (Hooge and Eichenlaub 1999) of ArcView. Nest sites and random points were each buffered with a 250-, 500-, 750- and 1000-m radius (hereafter referred to as 19.6 ha, 78.5 ha, 176.7 ha, or 314.1 ha area, respectively). These radii were selected because the resulting buffered area corresponded well to bobwhite home range sizes detected for our study area (38 to 171 ha; Parnell et al. 2002). Buffered nest sites and random points were intersected with the study area map using the ArcView Geoprocessing Wizard. Polygons (i.e., landscapes) from the intersection were converted from shape files to coverages with Arc/Info 8 GIS (Environmental Systems Research Institute 1999*a*). FRAGSTATS*ARC (Pacific Meridian Resources 2000) integrity checks were used to identify overlapping polygons and missing attribute information. Errors detected were corrected in the Arc/Info coverages. Patch, class, and landscape level metrics (McGarigal and Marks 1995) were calculated from landscapes with FRAGSTATS*ARC. Hardwood, fallow field, open canopy planted pine, and closed canopy pine habitat classifications were the class level metrics evaluated, and included with landscape level metrics for logistic regression analysis.

Data Analysis.— Logistic regression (Afifi and Clark 1990) was used to develop a predictive model of nest site selection at 4 landscape scales (i.e., 19.6 ha, 78.5 ha, 176.7 ha, and 314.1 ha areas), based on class and landscape metrics. From the class and landscape level metrics produced for the landscape coverages, we selected 14 metrics to be evaluated for possible inclusion in logistic regression as predictor variables. Metrics selected were chosen *a priori* to avoid redundancy among measurements, and based on perceived biological relevance to the dependent variable and their relevance to the objectives of this study (Penhollow and Stauffer 2000). Correlation diagnostics were performed on the 14 variables selected. Five variables were subsequently removed from further analysis. The 9 variables chosen for inclusion in the logistic regression procedure were: patch density (PD), patch size coefficient of variation (PSCV), total edge contrast index (TECI), Shannon's evenness index (SHEI), interspersion and juxtaposition index (IJI), percentage of the landscape composed of closed-canopy pine (CCP), percentage of the landscape composed of fallow fields (Fld), percentage of the landscape composed of hardwoods (Hwd), and percentage of the landscape composed of open-canopy planted pine (OCPP; Table 3.2). Variable IJI was not included in the analysis of the 19.6 ha area landscape because around several random nest sites there were too few patches to calculate this index (see McGarigal and Marks 1995).

Remaining variables were entered into a logistic regression procedure. Because it is possible to obtain statistically significant results that do not predict well (Afifi and Clark 1996:293), we wanted to know what variable(s) would predict, correctly, a large percentage of the time ($70%), indicating variables' biological relevance to bobwhite management. To avoid an over-fit model we used a logistic regression macro (C. T. Moore, D. B. Warnell School of Forest Resources, University of Georgia, Athens, Georgia, USA) in Statistical Analysis System software (SAS; SAS Institute 1996) that yielded a corrected Akaike's Information Criterion (AICc) score (Akaike 1973). The AICc score macro penalized for additional variable entry and it provided a percent of the events correctly classified. All possible variables (global model) were entered into the SAS macro to obtain all combinations of variable models (subset models) ranked from lowest ("best") to highest AICc scores. The lowest AICc model from the AICc macro was entered into a SAS macro (C. T. Moore, D. B. Warnell School of Forest Resources, University of Georgia, Athens, Georgia, USA) that performed a Monte Carlo cross-validation (Shao 1993). The number of cross-validation iterations was set at $1,000, and the proportion of data withheld for validation was based on the number of variables in the model being cross-validated (C. T. Moore, D. B. Warnell School of Forest Resources, University of Georgia, Athens, Georgia, USA). Fifty percent, 40%, 35%, 30%, and 30% of the data were withheld to validate 1-, 2-, 3-, 4-, or 5-variable models, respectively.

Because models with AICc scores within 1-2 units of the best model have substantial support and should receive consideration in making inferences (Burnham and Anderson 1998), we evaluated and reported by frequency the number of times a particular variable occurred in a model within 2 units of the best model selected by the lowest AICc score. The number of models within this range was reported. This procedure allowed us to qualitatively evaluate the pattern of variable selection over several models within each scale and variable selection across scales.

RESULTS

Nest statistics.—From 1997-2000, 29 of 39 bobwhite nests were first nest attempts. Sixteen first nest attempts were incubated by females (3 adults, 13 juveniles), and 13 nests were located by tracking males (7 adults, 6 juveniles) that were either incubating a nest or were paired with an unmarked female. One nest was located by chance and incubated by an unmarked bobwhite. Eight second nest attempts occurred after both successful and unsuccessful first nest attempts. One juvenile female attempted a third nest after the first one was depredated and the second nest hatched successfully. Most re-nest attempts (7 of 10) were <340 m from the first nest attempt and 4 of the re-nest attempts were in the same habitat patch or type. Five of the re-nest attempts were in different habitat types. One re-nest attempt was >2,730 m from the first nest attempt.

Habitat types selected by bobwhites for nest sites included agricultural fields (n = 1), closed-canopy pine (n = 13), fallow fields (n = 17), hardwoods (n = 1), and open-canopy planted pine (n = 7). At least one successful nest was found in each habitat type except hardwoods. In the fallow field habitat type, 5 nests were successful and 9 nests failed. Two nests were not monitored to the end of the incubation period due to field constraints, and 1 nest was abandoned shortly after the nesting bobwhite was flushed. Nine nests were successful and 1 nest failed in the closed-canopy pine habitat type. Two nests were abandoned for unknown reasons. In all field seasons, 69.2% of nests located in closed-canopy pine were <25 m from the edge. In the open-canopy planted pine habitat type, 5 nests were successful and 2 nests failed.

Models.—Best models for 19.6 ha, 78.5 ha, 176.7 ha, and 314.1 ha areas contained 1-variable, 2-variables, 5-variables, and 4-variables, respectively (Table 3.3). After cross validation, the models' mean percent of correctly classified nest and random site locations ranged from 60.0-69.5%. The variable OCPP occurred in each best model and the variable's coefficient was positively related to the occurrence of a bobwhite nest for each model. The variable PD was also positively related to the occurrence of a bobwhite nest and was present in best models at 3 scales (78.5 ha, 176.7 ha, and 314.1 ha areas). Variable's IJI and Fld occurred in best models at 2 scales (176.7 ha and 314.1 ha areas) and were negatively related to the occurrence of a nest. The variable CCP occurred at 1 scale (176.7 ha area) and was positively related to the occurrence of a nest. Omission errors (i.e., species detected where not predicted) ranged from 10.3% at the

176.7-ha scale to 22.4% at the 19.5-ha scale. Commission errors (i.e., species predicted but not detected) ranged from 5.2% at the 19.5-ha scale to 13.8% at the 78.5- and 176.7-ha scales.

When considering the frequency with which the possible predictor variables occurred in models within 2 AICc scores of the best model, several trends were observed. Frequency of occurrence ranged from 0% to 100% and number of models within 2 AICc scores of the best model ranged from 2 to 15 (Table 3.4). Four variables (PD, CPP, Fld, and OCPP) occur at least once at each of the landscape scales. The variable IJI was not included as a possible variable for the 19.6-ha scale, but does appear in at least one model in the other scales in which it was a possible variable. The PD and OCPP variables at all scales generally occurred in most models (> 50%). Both the IJI and Fld variables' frequency in the models increased as the landscape area increased. Coefficients for the variables PD, SHEI, CPP, and OCPP were positive in all models and at all scales in which they appeared. Coefficients for the variables PSCV, IJI, and Hwd were negative in all models and at all scales. Coefficients for the variables TECI and Fld were positive in all models they appeared in at the 19.6-ha scale, but were negative in all models at the other scales.

DISCUSSION

As Burger et al. (1995) demonstrated and our data supported, female northern bobwhites often attempt more than one nest. Our data indicated that 44.4% of re-nest attempts are within the same habitat patch and type, and 77.7% are within 330 m from the first nest attempt. Lack of independence of multiple nests from the same female bobwhite in the same year made assessment of nest site location to landscape structure difficult. We chose to error on the side of caution and while doing so found evidence that several variables quantifying landscape structure were influential at several scales in predicting nest site selection by bobwhites. Two of the more consistent variables were PD and OCPP.

Patch density is a fundamental aspect of landscape structure, but limited in interpretation. It does not indicate diversity or evenness of the landscape but it does indicate degree of fragmentation of the landscape when coupled with patch type (i.e., the greater the patch density for a particular patch type the greater the fragmentation of that patch type). When interpreted over the entire landscape mosaic it serves as a good spatial heterogeneity index (McGarigal and Mark 1995). Our best models for the 78.5-, 176.7-, and 314.1-ha scales predicted a bobwhite nest site as the spatial heterogeneity of patch density increased within landscape surrounding the nest sites. This does not imply an increase in patch diversity, but one would expect that the greater the patch heterogeneity, the greater the increase in patch diversity and increase in edges in the landscape. Such a mosaic of habitat patches would result in an increased likelihood of a bobwhite's, and eventually a brood's, needs (e.g., food, shelter, water) being available within a smaller area.

The percentage of open-canopy planted pine was low (5.2%) in our study area, yet 18% of bobwhite nests in our study were located in this habitat and 71% were successful hatches. Nesting occurred in both young plantations (<7 years old) and row-thinned older plantations (>7 years old). Further, OCPP was selected as the sole predictor variable in the best model for nest site selection at the 19.6 ha area scale, and was in the best model of each of the other 3 scales. Quantitative modeling and qualitative evaluation of variables across scales suggested that OCPP was a preferred habitat type across the landscape. Thinning CRP pine plantations in the Southeast would provide early successional habitat for bobwhites on a local level.

The variable CCP was only selected at 1 scale (i.e., 176.7 ha) in a best model. Thirteen nests were in CCP and 9 were successful. Most CCP was composed of planted pine plantations and most nests (69.2%) were <25 m from the edge of the pine stands. The edge of CCP stands supported the greatest vegetative structure and diversity with increasing lack of diversity father into the stands (C. G. White, University of Georgia, personal observation). Benefits to bobwhite of CCP stands need further investigation. Parnell et al. (2002) reported that CCP was not selected as home range habitat within their study area, and Lewis (1999) reported little use of CCP by radio-marked bobwhite. Lewis (1999) documented more dead bobwhites associated with closed-canopy pine than would be expected according to the amount of use of that habitat type. It was unknown if initial predation of bobwhites occurred in CCP or if predators carried them there. It is possible that any reproductive gain in this habitat type from nesting would be offset by juvenile and adult mortality.

The variable IJI occurred in best models for the 2 largest landscape scales (i.e., 176.7 ha, 314.1 ha) examined. Higher values of this index result when patch types are well interspersed (McGarigal and Marks 1995). Negative coefficients associated with IJI when predicting nest selection indicated that bobwhites were selecting sites with habitat types that were not equally adjacent to one another. Not all habitat types are created equally for bobwhite use and it could be expected that an area with high patch density but more patches of a favorable habitat (i.e., habitat that provides protection, food, etc.)

would be selected over an area with a complete diversity of patch types and equal proportion since some of these habitat types may not be beneficial to quail. For example, Staller (2001) conducted a nest study that found that bobwhite nest sites were located farther away from hardwood drains than random sites. Thus, a nest site surrounded by a high interspersion would include hardwood drains in a proportion that may be unusable or detrimental to nesting or brooding bobwhite. A low interspersion indicates a disproportionate distribution of patch type adjacencies (McGarigal and Marks 1995). It is logical to assume that not all patch type adjacencies are created equal.

It was surprising that Fld was negatively related to nest site selection at the 2 largest landscape scales (176.7 ha and 314.1 ha). At the 19.6-ha scale, the coefficient was positive but at the other scales the Fld coefficient was negative. Previous work (Lewis 1999, Parnell et al. 2002) on our study areas found that fallow field habitats were used by bobwhites in greater proportion than they occurred.

In our study and others (see Stoddard 1931, Rosene 1969, Klimstra and Roseberry 1975), most nesting occurred in fallow fields, but generally nests were located near field edges (Stoddard 1931, Rosene 1969). In our study, 80% of nest sites in fallow fields used to model prediction locations were located <25 m from a field edge. Only 6 of the random sites were located in fallow field habitat and none of these locations was <25 m from a field edge. The average percentage of fallow field around random sites at the 176.7-ha and 314.1-ha scales was 18.9% (SD = 11.7%) and 18.0% (SD = 9.5%), compared to 16.6% (SD = 9.3%) and 14.9% (SD = 7.7%), at the nest sites' 176.7-ha and 314.1-ha scales, respectively. The fallow field habitat type patch size ranged from 0.2 ha to 186.3 ha with a mean of 5.7 (SE = 9.7) in our study area, varied in habitat description (e.g., fallow, 2-4 year clearcut, etc.), and constituted 11.9% of the study area. We realize that different sized landscape areas are affected by size of the habitat types and the distribution of each of the habitat types.

We suggest multiple reasons why, at a very fine scale, fallow fields in our study site were a positive influence on nest site selection, but that at coarser scales their influence changed. First, while fallow fields are very important for nesting locations, it is the edge of the fallow fields that harbored most nest locations. Larger fields would occupy more of the buffered area around a nest or random site, but less of the field would be utilized because it contained more area per edge. We noticed that a few of our random points occurred in large extents of fallow field, while at the finer scales (i.e., 19.6 and 78.5 ha area) fewer random points were centered in fallow field habitat. Second, we have suggested that not all edge types are created equally, and fields adjacent to hardwood drains may experience more nest or brood predation. Our own evaluation of the landscape around nest sites indicates a negative relationship at several scales between the percent of hardwood in the landscape and a nest site. Thus, if a large portion of the fallow field borders the hardwood habitat then these fallow field areas may be less desirable for bobwhites. Third, fallow fields far away (e.g., > 500 m) from a nesting bobwhite have little immediate impact on the bobwhite and brood. Immediate needs of the bobwhite and brood would be met within a short distance, and at a finer scale, the fallow field within which the nest is located, together with a diversity of surrounding habitat, meets these needs. Further research and a larger sample are needed to explain the complexities of this and all variables. What is apparent is that fallow field habitat is used extensively in the spring and summer by bobwhites, and for nesting locations.

Several variables maybe useful at multiple scales in predicting bobwhite nest sites, as indicated by the frequency and consistency with which possible variables occurred in models within 2 AICc scores of the best model. PD and OCPP stood out in our analysis, but several other variables were included within and between scales. It is our opinion that this may be an indication of slack in the configuration of habitat patches for bobwhites. Guthery (1999) hypothesized the concept of slack in the configuration of habitat patches for bobwhites. Different patch configurations may result in landscapes of equal and optimal value to bobwhites. One possible reason for this, as reported by Guthery (1999), is because patch types have interchangeable functions. The consistent occurrence of a few variables and the possibility of other strong models as indicated by AICc scores may indicate that patch configurations lead to different combinations of landscape structure that may provide an equal or acceptable range of habitat for bobwhite.

The mean percent correct classification rates of the top logistic regression models were similar to the percentage (65%) reported in many field studies (C. T. Moore, University of Georgia, unpublished data) but below what we would desire. By using the AICc scores to determine the best models for each scale we attempted to select for parsimonious models that achieved a good balance between bias and precision (C. T. Moore, University of Georgia, personal communication). We believe that by using only one nest per bird per year, selecting variables *a priori*, cross-validating, and using AICc scores, we appropriately quantified the data and allowed a better "best" model selection at each scale. Further, by evaluating the frequency at which possible predictor variables were included in models that were within 2 AICc scores of the top model, we were able to assess the general trend within models and across scales. We were limited by sample size constraints but note that the study area is "typical" of quail habitat found in less intensive quail management areas of the Southeast as opposed to the habitat found in more intensively managed plantations in south Georgia, north Florida, and in some other locations (e.g., Texas and Oklahoma). Caution should be exerted when interpreting any model until validations with data from other studies can be done. However, we have presented some of the first results evaluating the relationship of bobwhite nest site location to the surrounding landscape at various scales.

MANAGEMENT IMPLICATIONS

Our study is not the first to discuss the improvements to northern bobwhite habitat that thinning pine plantations would bring (Stoddard 1931, Rosene 1969, Lee 1994, Lewis 1999, Parnell et al. 2002), but it is the first to quantify the importance of open canopy planted pine in the landscape structure of the Southeast around nest sites at various scales. The CRP program has influenced the landscape in the Southeast by converting marginal cropland primarily into pine plantations. Northern bobwhite management in CRP pine plantations requires both within patch and patch diversity (i.e., diversity within the landscape). With over 48,963 ha in Georgia and 42,053 ha in South Carolina alone (Burger 2000), of established (i.e., older than 10 years) CRP pine plantations, an enormous opportunity exists to use thinning and openings to create within patch diversity and subsequent diversity in the landscape. Based on our findings and experiences, thinning and creating openings in CRP pine plantations should provide increased nesting opportunity for bobwhites. The benefit of open canopy planted pine for bobwhite will vary by patch and over time in a few short years. Since early successional habitat in thinned pine stands will be ephemeral, follow-up management will be necessary to knock back succession. A variety of management practices (e.g., burning, discing, herbicides, etc.) can be implemented to prolong or arrest the succession stage at the physical and vegetative structure desired for bobwhite management (Landers and Mueller 1986, Melchiors 1991, Thackston and Whitney 2001). Follow up research on modifications to CRP pine plantations would indicate intensity and duration of use by nesting and possible use by brood-rearing bobwhites.

Our study is also the first to quantitatively evaluate the relationship between landscape structure and nest site selection by bobwhites. Patch density and open canopy planted pine were consistent variables in the landscape around nest sites compared to random sites. Patch density could be increased in large monotypic stands of agricultural fields and closed canopy planted pine stands by interspersion of fallow field and thins, respectively. Evidence of several strong models, in addition to the best model selected at the various scales, indicate that landscapes can be structured in several ways and still be functionally equivalent (Guthery 1999) for bobwhite use.

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Table 3.1. Habitat types and their composition, delineated for the classification and digitizing of the study area in Burke County, Georgia, USA.

Habitat type	Composition
Agricultural fields	Cultivated fields, pecan orchards, <1 year old clearcuts, pasture, hay fields, mowed yards, exposed soils
Closed-canopy pine	Managed planted pine stands at canopy closure (typically >5 years old), and natural stand composed of >50% pines >20 years old, or patches ≥0.8 ha in size in large forested hardwood tracts (>12 ha)
Fallow fields	Fallow and idle areas, 1-4 year old clearcuts, rights-of way, (typically #5 years)
Hardwoods	Stand composed of 50% bottomland and/or upland hardwoods >5 years old
Hedgerow	Linear or curvilinear habitat type that is 8 – 15 m in width and longer than it is wide, and forms an edge with or through another habitat type(s)
Open-canopy planted pine	Thinned, managed pine plantations, and young planted pine (typically #5 years)
Unavailable	Residential areas (houses or large buildings), roads (major paved or unpaved road with ≥2 lanes, and water (permanent or semi-permanent open ponds >0.2 ha)

Table 3.2. Description of class and landscape measurements[a] used as predictor variables in the development of logistic regression models for northern bobwhite nest site prediction in Burke County (1997-2000), Georgia, USA.

Mnemonic code	Units	Description
PD	no./100 ha	Patch density. Number of habitat patches per unit area.
PSCV	%	Patch size coefficient of variation. Measures relative variability of patch size.
TECI	%	Total edge contrast index. Quantifies edge contrast for the landscape as a whole, ignoring patch average.
SHEI	0 # SHEI # 1	Shannon's evenness index. A diversity index that measures the distribution of area among patch types. A measure of 1 equals perfects evenness.
IJI	%	Interspersion and juxtaposition index. Measures the level of patch interspersion relative to the maximum possible.
CCP	%	Percentage of the landscape composed of closed canopy pine.
Fld	%	Percentage of the landscape composed of fallow field.
Hwd	%	Percentage of the landscape composed of hardwoods.
OCPP	%	Percentage of the landscape composed of open canopy planted pine.

[a] See McGarigal and Marks (1995) for formulas and more detailed descriptions of habitat measures.

Table 3.3. Best model coefficients and standard errors (SE), corrected Akaike's Information Criteria (AICc), and cross validation results from logistic regression analysis at the landscape level for northern bobwhite nests from 1997-2000, Burke County, Georgia, USA. Sample size for all procedures was 58.

		Predictor variable[a]						Correctly classified (%)[b]	
Landscape area (ha)	Intercept	OCPP	PD	CCP	IJI[c]	Field	AICc	0	SE
19.6	-0.562	0.088					74.467	69.29	0.25
	(0.330)	(0.034)							
78.5	-1.857	0.050	0.060				80.281	60.00	0.24
	(0.885)	(0.028)	(0.032)						
176.7	3.971	0.129	0.185	0.061	-0.129	-0.063	73.984	66.36	0.30
	(2.728)	(0.048)	(0.087)	(0.033)	(0.051)	(0.033)			
314.1	5.560	0.231	0.288		-0.150	-0.099	71.379	69.46	0.29
	(3.323)	(0.072)	(0.120)		(0.059)	(0.044)			

[a] Descriptions for predictor variables can be found in Table 3.2.

[b] Cross validation results based on 1,200 iterations and with-holding a proportion of the observations.

[c] IJI was not included as a potential predictor variable in the 19.6 ha area logistic regression analyses.

Table 3.4. Frequency with which possible predictor variables occurred within accepted models based on corrected Akaike's Information Criteria (AICc; Burnham and Anderson 1998) for northern bobwhite nest site selection based on 29 nests and 29 random sites without nests, 1997-2000, Burke County, Georgia, USA.

	Frequency of predictor variable[a] in accepted models (%)									
Landscape area (ha)	PD	PSCV	TECI	SHEI	IJI	CCP	Fld	Hwd	OCPP	# of models
19.6	20.0	0.0	20.0	0.0	[b]	20.0	20.0	20.0	100	5
78.5	73.3	0.0	46.7	0.0	13.3	46.7	20.0	6.7	53.3	15
176.7	100	0.0	0.0	0.0	100	50.0	50.0	0.0	100	2
314.1	87.5	25.0	37.5	37.5	87.5	12.5	100	12.5	75.0	8

[a] Descriptions for predictor variables can be found in Table 3.2.

[b] IJI was not included as a potential predictor variable in models based on the 19.6 ha landscape area.

CHAPTER 4

PREDICTING EASTERN WILD TURKEY LOCATIONS IN A LANDSCAPE DOMINATED BY AGRICULTURAL AND SILVICULTURAL PRACTICES[1]

[1]White, C. G., C. T. Moore, S. H. Schweitzer, and J. J. Morgan. To be submitted to The Journal of Wildlife Management.

ABSTRACT: Spatial location and frequency of land cover types in the landscape greatly influence the amount of edge and type of land cover edge. The Conservation Reserve Program (CRP) altered the interspersion of land cover and proportion of land cover edge available in landscapes of the Southeast. Eastern wild turkey (*Meleagris gallopavo silvestris*) use of land cover types in the Southeast has been well documented in heavily timbered landscapes but little work has been done to evaluate the effects of the changing mosaic in a mixed agricultural/silvicultural landscape. We used logistic regression to model the response of wild turkeys to land cover types and land cover edge types. Hardwood land cover was overwhelmingly the best predictor of female breeding, female post-incubating, and male post-breeding activity. Our male breeding model predicted avoidance of field/hardwood edge and agriculture/closed-canopy planted pine edge, and shorter distances to closed-canopy planted pine/field edge during the spring than random locations. Results from this study supported a habitat use versus availability study of this area and added insights into what land cover edge types should be promoted under the CRP for wild turkey management. We urge careful consideration to any further removal of large extents of bottomland hardwood stand in areas of intensive agricultural and silvicultural practices. Replacement of agricultural fields by pine plantations may have created more landscape evenness in some landscapes, and in other landscapes offered a diverse choice of land cover types for wild turkey use. Thinning 13 to 15-year old pine plantations by $33% would increase stand diversity and possibly favor increased use of edges by wild turkey.

INTRODUCTION

The interspersion of fallow fields, hardwood stands, pine plantations, and cropland, found in the southeastern United States creates the landscape mosaic of cover types in which wildlife live. Since the inception of the CRP in 1985, >830,202 ha of farmland have been converted to tree plantings (mostly loblolly pine [Pinus taeda]) in the Southeast (Farm Service Agency 1997). The conversion of cropland to pine plantings has affected the landscape mosaic. Allen (1993) reported that the establishment of pine plantations under the CRP might have eliminated thousands of acres of high-quality nesting, brood rearing, and foraging habitat in the Southeast. However, little work has been done to evaluate the effects of the changing landscape mosaic on wildlife use and movements.

Eastern wild turkey use of land cover types in the Southeast has been well documented in heavily timbered landscapes (Wigley et al. 1985, Exum et al. 1987, Burke et al. 1990, Hurst and Dickson 1992, Wunz and Pack 1992, Palmer et al. 1993, Allen et al. 1996, Miller et al. 1999). It is generally accepted that mature stands of mixed hardwoods, with relatively open understories, interspersed with scattered clearings and groups of sawtimber-sized conifers combine to form high quality wild turkey habitat in the Southeast (Allen et al. 1996). However, the benefit to wild turkey populations of even-aged short rotation pine plantations in heavily timbered landscapes is variable and use is dependent upon sex and age of turkeys (Wigley et al. 1985, Exum et al. 1987, Bidwell et al. 1989, Burke et al. 1990, Allen et al. 1996, Morgan 2000). Use of pine plantations by wild turkeys within a mixed agricultural and timber landscape, such as created by the CRP, has only recently been quantitatively analyzed and reported (Morgan 2000).

It is recognized that the suitability of pine plantations and other land cover types for wild turkey use and benefit are affected by the spatial configuration of land cover types (Felix et al. 1986, Holbrook et al. 1987, Allen et al. 1996). Allen et al. (1996) stated that wildlife habitat can increase, and landscape-level habitat fragmentation and composition addressed, by the correct spatial placement of pine plantings. But how do we evaluate landscape-level habitat structure? The increased ability of researchers to evaluate effects of habitat type configuration, composition, and fragmentation on wildlife phenomena is due to increased use of geographic information systems (GIS), patch or landscape metrics, multivariate statistics, and modeling to examine relationships between wildlife locations and habitat types (Roseberry et al. 1994, Robinson et al. 1995, Ripple et al. 1997, Roseberry and Sudkamp 1998, Merrill et al. 1999, Miller et al. 2000, Penhollow and Stauffer 2000).

We used GIS to calculate distance measurements from wild turkey locations to the nearest land cover types and land cover edge types available in a landscape dominated by cropland, pastureland, tree plantings, and hardwoods. Logistic regression was used to model eastern wild turkey use of habitat types found within the landscape (Miller et al. 2000). Our objective was to determine responses of eastern wild turkey to the landscape configuration and composition available to them currently as a result of past land management decisions, including those facilitated by the CRP over the last 15 years. We tested the hypothesis that eastern wild turkeys would show preference for specific land cover edge types.

STUDY AREA

Our research was conducted on Di-Lane Plantation Wildlife Management Area (WMA) (32° 57' N 82° 04' W) in the Upper Coastal Plain physiographic region, Burke County, Georgia. Di-Lane Plantation WMA is a 3,278-ha tract managed primarily for northern bobwhite (*Colinus virginianus*) by the Georgia Department of Natural Resources (GA DNR). Prominent land cover types included: 1,666 ha of mixed pine-hardwoods, 849 ha of fallow fields, and 497 ha of planted pines. In 1986, 286 ha were enrolled in the CRP and planted in loblolly pines at 1,793 trees/ha. Movements of radio-marked turkeys beyond the Di-Lane Plantation WMA boundary and a desired buffer of ≥2 km around turkey locations, increased the study area to >22,878 ha. The composition of the final Di-Lane Plantation WMA and surrounding study area (hereafter referred to as the Di-Lane study area) included upland and bottomland hardwoods (32%), cropland (25%), closed-canopy planted pines (15%), fallow fields and pastures (14%), old ($5 year old) clearcuts (5%), mature ($20 year old) pines (4%), open-canopy planted pines (3%), and other (2% that included residential areas, roads, and water).

METHODS

Capture and Radio Telemetry

From January – March 1998 and 1999, eastern wild turkey were captured with rocket nets in baited fields (Wunz 1979). Each bird was banded with a uniquely marked leg band and radio-marked with a 110-g backpack style radio transmitter with motion sensor (Telonics, Inc., Mesa, Arizona, USA). Before release from the trap site the sex, mass, and age of each bird was recorded (Williams and Austin 1988). Research was conducted under the University of Georgia IACUC Protocol No. A960216C2.

During each spring and summer, 2 observers used 3-element Yagi antennas and R4000 receivers (Advanced Telemetry Systems, Anoka, Minnesota, USA) to record $2 bearings from permanent telemetry stations (n = 336) to each radio-marked turkey (Cochran and Lord 1963). In 1998, >90% of bearing sets were collected in #5 min, and in 1999 bearings were recorded simultaneously. To ensure bearings crossed and the estimated location was reasonable, bearing sets were mapped in the field on 1:79-m scale aerial photographs. Each turkey was located $3 times a week with $1 location in each of 3 time periods (0600-1100 hr, 1101-1500 hr, 1501-1800 hr). For each brooding hen $6 locations a week were recorded during the 2-week post-hatch period. Tracking began in late March and ended 15 August 1998 and 31 July 1999. The breeding season ended 11 May 1998 and 10 May 1999 (Morgan 2000).

Permanent telemetry stations, visual observations, and offset locations (birds within 100 m of observer) were recorded in Universal Transverse Mercator (UTM) coordinates in Zone 17 North using the North American Datum 1983 (NAD83) with a Trimble™ GeoExplorer II hand-held global positioning system (GPS) receiver (Trimble Navigation Ltd., Sunnyvale, California). Visual observations and offset locations accounted for 17% of all wild turkey locations (Morgan 2000). Telemetry stations and observed turkey locations were differentially corrected using data from 1 of 4 nearby (#240 km) base stations in South Carolina using Trimble™ Pathfinder Office software (Trimble Navigation Ltd., Sunnyvale, California, USA). Location of a Signal (LOAS™) software (Ecological Software Solutions, Sacramento, California, USA) and its best biangulation estimator were used to determine turkey locations. Bearing error tests (White and Garrot 1990) were conducted by hiding transmitters in known locations representing various land cover types. In 1998 and 1999, the mean bearing error was 8.7 ± 1.0 degrees (n = 158) and 9.8 ± 0.7 degrees (n = 149), respectively; the mean bearing length for all bearings was 439.2 ± 7.7 m (n = 3,741) (Morgan 2000).

Land Cover Delineation

Land cover types located on the Di-Lane study area were digitized at a scale ≥1:3,000 m, referencing U.S. Geological Survey 1993 Digital Orthophoto Quarter Quadrangles (DOQQ) with a root mean square error (RMSE) of ≤1.6 m in ESRI™ ArcView (Environmental Systems Research Institute 1999). Except for residential areas, the smallest mapping unit was 0.4 ha. Residential areas were digitized in mapping units < 0.4 ha. Our knowledge of the area, remote imagery, and inspection of unfamiliar areas were used to correctly classify, modify, and update 1993 landscape polygons to represent 1998 and 1999 landscape. Land cover types delineated included active agricultural field (cropland, pecan orchards), closed-canopy planted pine, fallow field, hardwood, mature pine (>20 year old), old clearcut (5-15 year old), open-canopy planted pine, and unavailable areas (Table 4.1). We carefully verified the digital coverage while acquiring and recording turkey movements in the field.

Fallow field cover type included fallow and idle fields (fallow or idle for $1 year) as well as pasture and mowed areas. Rights-of-way (gas and power lines) were also defined as fallow field cover type except for portions of a right-of-way that intersected an agricultural field. Portions of rights-of-way intersecting an agricultural field were defined as active agriculture. We defined stands composed of >50% hardwood that were >15 years old as hardwood cover type. No distinction was made between bottomland and upland hardwoods, but most stands defined as hardwood were located along river bottoms and floodplains. Oak (*Quercus* spp.) and hickory (*Carya* spp.) dominated hardwood forests in the study area (Morgan 2000). In large forested tracts (>12 ha), composed of >50% hardwoods, mature pine was identified and digitized only if the mature pine area dominated an area of ≥0.8 ha. Young managed planted pine stands were defined as open-canopy planted pine until approximately 5 years old. Managed pine stands with closed canopy (typically $5 years old in our study area) were defined as closed-canopy planted pine. Managed pine stands >5 years old and thinned were classified as open-canopy planted pine. Pine stands in our study area were primarily planted to loblolly pine. We defined residential housing and commercial buildings, major paved or unpaved roads with ≥2 lanes, and permanent or semi-permanent open ponds (>0.2 ha) as unavailable area.

Land Cover Analysis

Telemetry locations of eastern wild turkeys were sorted by sex and seasonal behavior (e.g., pre-breeding, breeding, post-breeding). The breeding and post-breeding periods for males and non-nesting females were delineated by identifying the date on which 90% of radio-marked hens began incubation. Seasons for nesting females were defined as breeding and post-incubation. Telemetry locations of females were sorted into successful and unsuccessful nesters for the post-incubation period. A nest was considered successful if $1 egg hatched. Telemetry locations of non-nesting females during the post-breeding period and of unsuccessful nesting females during the post-incubation period were pooled, and hereafter will be collectively referred to as unsuccessful nesters in the post-incubation period. Minimum convex polygon home ranges were constructed using telemetry locations of males and females with $10 locations each (Morgan 2000), during each delineated season using the Animal Movement (Hooge and Eichenlaub 1997) extension developed for ArcView. Random points were generated within each of the male and female seasonal home range polygons using Animal Movement and a uniform random distribution. The number of random points generated within a home range matched the number of telemetry-locations used to generate the home range. Hence, we matched the actual turkey telemetry locations for a single real turkey with an equal number of randomly generated points within the same home range. This procedure allowed us to treat the individual turkey and not the subset of turkey locations as the experimental unit for statistical comparison (Hurlbert 1984, Aebischer et al. 1993). To maximize sample size, male and female turkey data sets were each pooled over age class and years (White and Garrot 1990).

Our *a priori* independent variables of interest were distance measurements to the nearest land cover types and land cover edge types available in the landscape of the Di-Lane study area (Table 4.2). Distances to land cover and edges were calculated from the GIS land type coverage and turkey location coverage using ArcView and an ArcView extension (Jenness 2001). Land cover edges <15 m wide were not considered for distance measurements. Because old clearcuts and open-canopy planted pine occurred relatively rarely in the landscape and infrequently shared a border with the other land cover types, we included shared edge types containing these 2 variables in analyses. In addition, we only considered distance to unavailable habitat as a whole as opposed to its shared edge with other land cover types. Distances from each turkey telemetry location and each random point to the nearest land cover type were averaged to produce an interspersion index measurement (Miller et al. 2000) for turkey telemetry locations and random points (Table 4.2).

For each variable, statistical differences (*P* # 0.10) between the weighted means of the turkey telemetry and random point locations (paired samples) were tested using PROC UNIVARIATE (SAS Institute 1990:619). Logistic regression (Afifi and Clark 1990) was used to develop predictive models of wild turkey land cover type selection. Before development of a particular male or female season model, variables were tested for correlation (PROC CORR; SAS Institute 1990). Variables highly correlated with 1 or multiple other variables within a male or female season were eliminated from further use in the development of that particular model. To use the rule of 1 variable for every 10 samples (Williams and Titus 1988) and to keep our models general, we only developed models with 1-3 variables. To aid us in our logistic regression modeling we developed a logistic regression macro using Statistical Analysis System (SAS) software (SAS Institute 1999) that performed an analysis on the means of the landscape variables and yielded a corrected Akaike's Information Criterion (AICc) score (Akaike 1973, Burnham and Anderson 1998). In addition, the logistic regression macro provided model-averaged estimates for predicted models (Burnham and Anderson 1998) and performed a bootstrapping cross-validation procedure on the "best" model (i.e., lowest AICc score). The number of cross-validation iterations was set at $10,000.

Burnham and Anderson (1998:323) point out that models having AICc scores within 1-2 (units) of the best model have substantial support and should receive consideration in making inferences. Therefore, we evaluated and reported by frequency the number of times a particular variable occurred in a model within 2 units of the best model selected by the lowest AICc score. The number of models within this range was also reported. This procedure allowed us to qualitatively evaluate the pattern of variable selection within male and female seasons and across male and female seasons.

RESULTS

Twenty-eight male and 35 female turkeys were captured from 1998–1999 (Morgan 2000). Twelve males and 19 females had ≥10 locations for the breeding period and 13 males had ≥10 locations for the post-breeding period. Nine females were successful nesters and had ≥10 locations in the post-incubating period. Thirteen females were either unsuccessful nesters or did not nest and had ≥10 locations in the post-incubating period.

We used the weighted means from 3,134 individual turkey locations (1,567 turkey telemetry locations and 1,567 random point locations) in our model building and analysis. The male breeding season analyses consisted of 11 individual turkey home ranges with a combined total of 560 telemetry and random point locations. The male post-breeding season consisted of 13 individual turkey home ranges with a combined total of 964 telemetry and random point locations. The female breeding season data consisted of 16 individual turkey home ranges with a combined total of 560 telemetry and random point locations, the female post-incubation season data for successful nesters consisted of 9 individual turkey home ranges with a combined total of 588 telemetry and random point locations, and the female post-incubation season data of unsuccessful nesters consisted of 13 individual turkey home ranges with a combined total of 808 telemetry and random point locations.

The number of variables with significant ($P < 0.10$) weighted mean differences varied within male and female seasons. Differences between telemetry location and random point location weighted means of distances to CPP and Hwd were significant for females in the breeding season, and for unsuccessful nesters in the post-incubation season; females were farther from CPP and closer to Hwd then would be expected if their locations were random (Table 4.3). Female post-incubation, unsuccessful nester differences were also significant for Ag_MP, Fld_MP, Hwd_MP, and MP. These females were farther from Ag_MP and closer to Fld_MP, Hwd_MP, and MP than would be expected if locations were random. During the post-incubation season, females that were successful nesters did not significantly associate with any edge type. Males during the breeding season were farther from Ag_MP, CPP_Hwd, Fld_Hwd, Hwd_MP, MP, OCC, OPP, and Isp, and closer to Ag_Fld than would be expected if their locations were random (Table 4.4). Males during the post-breeding season were farther from CPP_Hwd, CPP_MP, CPP, and Una, and closer to Hwd than would be expected if their locations were random. The CPP_Hwd edge was the only land cover type to which male locations were farther than random during both breeding and post-breeding seasons.

Hens during the breeding season and unsuccessful nesters during the post-incubation season, and males during the post-breeding season selected habitats closer to Hwd then would be expected if their locations were random within the landscape. Hens during the breeding season, unsuccessful hens during the post-incubation season, and males during the post-breeding season were farther from CPP then would be expected if their locations were random. Unsuccessful hens during the post-incubation season and males during the breeding season were farther from Ag_MP and Hwd_MP than would be expected if locations were random. Unsuccessful hens during the post-incubation season were closer to MP and males during the breeding season were farther from MP than would be expected if locations were random.

Six variables were excluded from the female seasons' and 5 from the male seasons' logistic regression models due to high correlation (*r* $ 0.78) with one or more other variable (Table 4.3 and Table 4.4). In the female post-incubation successful nesters, and the male post-breeding regression analysis, the best models (lowest AICc score) included the intercept only. Therefore, we did not discard models with the next lowest AICc scores that included $1 land cover type variable (Table 4.5). Distance to Hwd was the only variable in best models for the female breeding; female post-incubation, successful nesters; and male post-breeding seasons. Variables in the best model for the female post-incubation, unsuccessful nesters season were distance to Hwd and distance to Ag_CPP (Table 4.5). The best model for the male breeding season included Ag_MP, CPP_Fld, and Fld_Hwd (Table 4.5). The cross-validation correct classification rate for the male breeding season best model was the highest (81.35%; SE = 0.16) of all models (Table 4.5).

When considering the frequency with which the possible predictor variables occurred in models within 2 AICc scores of the best model (and including the best model), several trends were observed. Thirteen variables were included in models and 9 of these variables occurred in $1 male or female season with a frequency $33.0%. Frequency of occurrence ranged from 0% to 100% and number of models within 2 AICc scores of the best, and including the best model, ranged from 3 to 11. The most frequently occurring variable in the top models within 4 of the 5 seasons was Hwd (Table

4.6). The variables Fld_Hwd and CPP_Hwd, respectively, were the most frequently occurring variables within the male breeding season models.

DISCUSSION

Spatial location and frequency of land cover types in the landscape greatly influence the amount and type of edge available. Promotion of edge habitat as being beneficial to game species is generally traced back to Leopold (1933). Wild turkey management in Georgia (Thackston et al. 1991) and elsewhere encourages an abundance of edge habitat. Turkeys' selection of land cover types based on distance of their telemetry locations to land cover types has been documented for some key life activities such as nesting (Holbrook et al. 1985, Seiss et al. 1990). These distance data have been used to model habitat selection of turkeys and subsequently they have been incorporated in habitat evaluation procedures or other modeling efforts (Armbruster and Lewis 1980, Schroeder 1985, Miller et al. 2000). However, the specific land cover edge types used by turkeys have received little quantitative evaluation. Due to our small sample size of radio-marked wild turkeys we did not expect highly predictive and repeatable models but we did expect to gain biological understanding of eastern wild turkey use of land cover types in landscapes dominated by agriculture and silviculture.

Indeed, we did not obtain highly predictive models in most instances; however, results from the weighted mean difference analyses and logistic regression modeling documented a repeated association between telemetry locations and hardwood stands during most male and female seasons (Fig. 4.1). Large contiguous tracts of hardwoods, occasionally interrupted by paved two-lane roads, criss-crossed our study area in a north to south and east to west fashion. These large tracts of hardwoods were composed primarily of bottomland hardwoods associated with major creek drainages. The importance of hardwoods to wild turkeys has been well documented as this habitat type provides forage and cover (Kennamer et al. 1980, Porter 1992), travel lanes between feeding areas, and roosting and loafing sites (Gehrken 1975, Holbrook et al. 1985). This finding compliments previous work conducted by Morgan (2000) who used compositional analysis (Aebischer et al. 1993), much of the same triangulation data and land cover GIS database, and similar male and female seasons, to document that mature hardwood stands were the most frequently used habitat across all season and sex combinations for Di-Lane Plantation WMA and surrounding areas.

Most habitat use vs. habitat availability studies, and distance to land cover type studies, fail to document affinity or lack thereof to specific types of edge. The male breeding season model detected a strong (81.35% after cross-validation) association between telemetry locations and 3 edge-associated variables. Our results show that males during the breeding season were farther from edges formed by field and hardwood than random locations, indicating an avoidance of this edge type even though hardwood and field (Lewis 1964, Speake et al. 1975, Healy and Nenno 1983, Peoples et al. 1995, Morgan 2000) importance and use is well documented. Since a large portion of the male breeding locations (Fig. 4.1) were located in large hardwood stands, mostly bottomland, it is possible that avoidance of edges formed by field and hardwood may not be avoidance, but a spurious result of occupying the interior of open bottomland hardwoods for breeding purposes. That would not necessarily explain, however, why other edge types composed of hardwood/land cover type are also not significant spurious variables.

In addition, some turkey locations during the breeding period were located in fallow fields. Wunz and Pack (1992) report that turkeys during the spring courtship prefer woods with open understory, or small clearings, or field edges. They do not directly comment on the edge created by the combination of these habitat types. They do report that turkey avoid habitats where understory vegetation reduces their vision, as well as areas that are repeatedly disturbed by people. We suspect that male turkeys may avoid the fallow field/hardwood edge borders in our study in the spring due to predators, including hunting and the increased human disturbance this brings. On the other hand, actual male turkey locations during the breeding season are closer to the closed-canopy planted pine/fallow field edge habitat. Since our study area consisted of closed-canopy planted pine relatively devoid of understory, and management practices in pine plantations often involve fire breaks around pine stands, this would create a courting display area with open understory and fewer visual obstructions.

The other variable important in predicting male locations during the breeding season was an increased distance away from agriculture/mature pine edge. Morgan (2000) found that male turkeys in our study area during the breeding season used mature pine relatively more frequently than any other habitat type, and used agricultural fields relatively little. Kurzejeski and Lewis (1990) reported that female turkeys in northern Missouri used cropland least of all the available habitat, except for one winter when mast production was low. Therefore, agriculture/mature pine edge does not appear to be used to a great extent during most seasons but may serve as an important edge type during winters with low mast availability. Obviously, the crop planted would also be important when considering turkey use of these edge types.

Other specific land cover edge types were included in the best models or occurred frequently in the models within 2 AICc scores of the best model. For example, the female post-incubation season model for unsuccessful nesters incorporated distance to agriculture/closed-canopy planted pine borders into the best model. As we just discussed, others have documented low use of agricultural fields during the spring and summer (Kurzjeski and Lewis 1990, Morgan 2000). Although Morgan (2000) documented preferred use of closed canopy planted pine by female turkeys in the post-incubation season, use of specific edge types around closed canopy planted pine appears to also be selective. Reasons for such selection are likely varied but could include risk of predation, travel accessibility along certain edge types, and diversity or lack thereof of fauna along certain edge types.

Finally, the correct classification rates of 4 of the 5 best logistic regression models were below the percentage (65%) reported in many field studies (C. T. Moore, University of Georgia, unpublished manuscript) and below what we would desire. However, our method of pairing random to actual turkey locations allowed us to better maintain the sampling unit as an individual turkey. Placing the emphasis on the individual turkey and not individual turkey locations could create bias because of disparity in number of points per individual turkey. We corrected this by weighting our analyses with the number of locations per turkey. This also enabled us to use all location data available as opposed to a subset of the data. By using the AICc scores to determine the best model, we attempted to select for parsimonious models that achieved a good balance between bias and precision. We believe that using the complete data set, treating the individual as the sampling unit, selecting *a priori* the variables, and using AICc scores more appropriately quantified the data and allowed a better "best" model selection.

MANAGEMENT IMPLICATIONS

Results support previous findings of habitat use versus availability analysis conducted on the Di-Lane Plantation WMA and surrounding areas (Morgan 2000). Miller et al. (2000) recently published a paper urging the coupling of habitat use versus availability analysis with predictive models to gain further insights into a species' habitat ecology. Our findings support the use of predictive models to add insight into habitat use versus habitat availability studies. Results not only supported previous evidence of hardwood importance in landscapes but also showed affinity for or against specific edge combinations of land cover types. Understanding what edges are beneficial or are not beneficial to a species can be as important as creating or changing a land cover type in the first place.

The United States Department of Agriculture's recommendations for thinning and/or opening pine stands for CRP re-enrollment could influence eastern wild turkey use of these areas. Our data suggest that use would depend on season and sex, as well as vegetative component of the newly created opening or thinning. For example, a male turkey in the breeding season may avoid the edge of a newly created opening if that opening edge is shared with hardwood, and the opening is allowed to act as a fallow field. However, evidence also indicates that openings in a pine stand could potentially create additional nesting habitat for turkey hens (Smith et al. 1990, Morgan 2000). Further, it was documented by us that a fallow field/closed canopy planted pine edge could be favorable for breeding male turkeys, and open canopy planted pines would also serve post-incubating females that successfully hatched a nest. We agree with the recommendation to row thin and/or open 13 to 15-year old pine stands by $33% to maximize a diversity of use by male and female wild turkeys of pine plantations under the CRP, but caution that effort will best be maximized only after careful consideration of where to place openings.

Hardwoods in our study area composed the greatest proportion (32%) of the defined landscape, but were also used proportionally more than what was available (Morgan 2000). Locations of eastern wild turkey in relation to hardwoods were extensive by both males and females during all the seasons. We urge thoughtful management of the hardwood component in a landscape dominated by agricultural and silvicultural practices. The role of hardwoods in such a landscape is diverse and the role as travel corridors may be essential for movement within a well diversified landscape, and among upland pine stands that lack proper forest structure (Burk et al. 1990, Palmer and Hurst 1996, Miller et al. 2000). Further research into wild turkey selection of land cover types in a mixed agricultural and silvicultural landscape should continue to evaluate the importance of specific land cover edge types.

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Table 4.1. Land cover types and their composition, delineated to digitize the Di-Lane study area, Burke County, Georgia, USA, 1998-1999.

Land cover type	Composition
Active Agriculture	Cultivated fields, pecan orchards, <1 year old clearcuts, exposed soils
Closed-canopy planted pine	Managed planted pine stands at canopy closure
Fallow fields	Fallow areas, pasture, mowed areas, 1-4 year old clearcuts, rights-of way
Hardwoods	Stand composed of 50% hardwoods >15 years old
Mature pine	Stand composed of >50% pines >20 years old
Old clearcuts	Stand composed of dense regeneration 5-15 years old
Open-canopy planted pine	Thinned, managed pine stands, <5 year old planted pine
Unavailable	Residential areas (houses or large buildings), roads (major paved or unpaved road with ≥2 lanes, and water (permanent or semi-permanent open ponds >0.2 ha)

Table 4.2. Land cover types and edge, and the interspersion index used as variables to quantify selection of landscape components by eastern wild turkey from 1998-1999, Di-Lane study area, Burke County, Georgia, USA. All distances are in meters.

Variable	Description (Distance to nearest land cover type and definition of Isp)
Ag_CPP	Agriculture field/closed-canopy planted pine edge
Ag_Fld	Agriculture field/fallow field edge
Ag_Hwd	Agriculture field/hardwood edge
Ag_MP	Agriculture field/mature pine edge
CPP_Fld	Closed-canopy planted pine/fallow field edge
CPP_Hwd	Closed-canopy planted pine /hardwood edge
CPP_MP	Closed-canopy planted pine/mature pine edge
Fld_Hwd	Fallow field/hardwood edge
Fld_MP	Fallow field/mature pine edge
Hwd_MP	Hardwood stand/mature pine edge
Ag	Agriculture field
CPP	Closed-canopy planted pine
Fld	Fallow field
Hwd	Hardwood stand
MP	Mature pine stand
OCC	Old clearcut
OPP	Open-canopy planted pine stand
Una	Unavailable land cover
Isp	Interspersion; average distance of all habitat types

Table 4.3. Difference between the weighted mean (SE) distance (m) values used in statistical analyses of 19 variables, for female wild turkey seasons (1998-1999), Di-Lane study area, Burke County, Georgia, USA.

	Weighted mean difference[a]					
	Breeding season		Post-incubation, successful nesters		Post-incubation, unsuccessful nesters	
Variable[b c]	0	SE	0	SE	0	SE
Ag_CPP	-9.2	41.2	-25.1	52.0	66.5	58.3
Ag_Fld[d]	-41.4	41.5	-20.7	43.8	13.1	46.6
Ag_Hwd[d]	-28.2	35.3	-2.7	40.9	24.6	36.3
Ag_MP[f]	-61.5	34.8	115.5	75.5	165.0	81.4
CPP_Fld[d]	9.1	24.7	-3.3	30.2	41.3	24.9
CPP_Hwd[d]	14.1	19.3	-2.5	30.6	26.6	25.9
CPP_MP	24.0	43.7	-16.5	52.1	-82.4	53.2
Fld_Hwd[d]	-1.4	12.9	-4.2	9.4	-4.8	11.7
Fld_MP[d f]	-42.1	41.1	-18.2	63.4	-62.8	35.1
Hwd_MP[d f]	-38.1	39.6	-18.2	46.4	-65.6	32.9
Ag	-33.3	36.8	-10.6	42.9	29.0	37.2
CPP[e f]	29.7	15.9	16.0	25.8	38.1	20.2
Fld	8.0	12.3	4.8	8.1	11.2	9.6
Hwd[e f]	-10.2	4.5	-20.0	11.0	-23.8	7.3
MP[f]	-40.3	39.2	20.5	46.2	-61.2	29.6
OCC	-49.4	50.6	-79.6	77.6	-49.5	39.5

Table 4.3. Continued.

	Weighted mean difference[a]					
	Breeding season		Post-incubation, successful nesters		Post-incubation, unsuccessful nesters	
Variable[b]	0	SE	0	SE	0	SE
OPP	13.1	27.6	-63.7	45.7	-63.9	43.5
Una	-29.0	26.4	59.3	43.6	48.1	47.3
Isp	-13.9	10.0	-9.2	16.5	-9.0	10.9

[a] Negative (-) sign indicates telemetry locations were closer than would be expected if their locations were random; positive (+) sign indicates telemetry locations were greater than would be expected if their locations were random.

[b] See Table 4.2 for variable description.

[c] No variables were significant at *P* # 0.10 for unsuccessful nesters during the post-incubation season.

[d] Variable excluded from $1 female season, when modeling with logistic regression, due to high correlation with other variable(s).

[e] Variable during the breeding season that was significant at *P* # 0.10.

[f] Variable during the post-incubation season for successful nesters that was significant at *P* # 0.10.

Table 4.4. Difference between the weighted mean (SE) distance (m) values used in statistical analyses of 19 variables, for male wild turkey seasons (1998-1999), Di-Lane study area, Burke County, Georgia, USA.

	Weighted mean difference[a]			
	Breeding season		Post-breeding season	
Variable[b]	0	SE	0	SE
Ag_CPP[c]	88.8	81.0	14.7	43.9
Ag_Fld[c d]	-114.6	60.8	32.7	87.0
Ag_Hwd[c]	48.2	64.5	-2.1	62.7
Ag_MP[d]	173.0	60.4	74.2	63.0
CPP_Fld	50.1	38.3	74.2	41.9
CPP_Hwd[c d e]	43.2	15.5	74.1	35.4
CPP_MP[e]	3.7	19.4	75.7	40.7
Fld_Hwd[d]	45.6	12.9	6.5	23.9
Fld_MP	9.0	44.1	21.1	17.2
Hwd_MP[c d]	37.7	17.3	-27.0	24.5
Ag	50.5	61.8	4.6	64.2
CPP[c e]	13.1	15.9	94.3	29.5
Fld[c]	26.3	22.6	15.8	20.1
Hwd[e]	-3.1	10.0	-18.3	7.2
MP[d]	43.6	17.3	-20.2	21.5
OCC[d]	86.1	37.0	-62.1	53.9
OPP[d]	70.5	49.4	37.1	37.1

Table 4.4. Continued.

	Weighted mean difference[a]			
	Breeding season		Post-breeding season	
Variable[b]	0	SE	0	SE
Una[e]	67.3	45.4	63.6	34.2
Isp[d]	44.3	14.8	14.4	79.9

[a] Negative (-) sign indicates telemetry locations were closer than would be expected if their locations were random; positive (+) sign indicates telemetry locations were greater than would be expected if their locations were random.

[b] See Table 4.2 for variable description.

[c] Variable excluded from $1 male season, when modeling with logistic regression, due to high correlation with other variable(s).

[d] Variable during the breeding season that was significant at *P* # 0.10.

[e] Variable during the post-breeding season that was significant at *P* # 0.10.

Table 4.5. Best model's averaged coefficients (SE), corrected Akaike's Information Criteria (AICc), and cross validation results from logistic regression analysis of eastern wild turkey and random locations (1998-1999), Di-Lane study area, Burke County, Georgia, USA.

		Predictor variable[a]						Correctly classified (%)[b]	
Sex and season	Intercept	Hwd	Ag_CPP	Ag_MP	CPP_Fld	Fld_Hwd	AICc	0	SE
Female breeding	1.169	-0.040					53.613	51.65	0.13
	(1.727)	(0.023)							
Female post-incubation	1.517	-0.047					27.534	47.43	0.18
(successful nesters)[c]	(3.838)	(0.038)							
Female post-incubation	2.505	-0.062	-0.002				34.097	59.83	0.15
(unsuccessful nesters)	(3.248)	(0.033)	(0.001)						
Male breeding	-12.427			0.007	-0.020	0.047	24.960	81.35	0.16
	(9.775)			(0.004)	(0.015)	(0.027)			

Table 4.5. Continued.

		Predictor variable[a]						Correctly Classified (%)[b]	
Sex and season	Intercept	Hwd	Ag_CPP	Ag_MP	CPP_Fld	Fld_Hwd	AICc	0	SE
Male post-breeding[c]	-2.391	-0.026					38.545	57.87	0.18
	(3.499)	(0.021)							

[a] Descriptions for predictor variables can be found in Table 4.2.

[b] Cross validation results based on $10,000 bootstrap iterations.

[c] Best model by lowest AICc score was the intercept only model; reported in this table is the model with the next lowest AICc score.

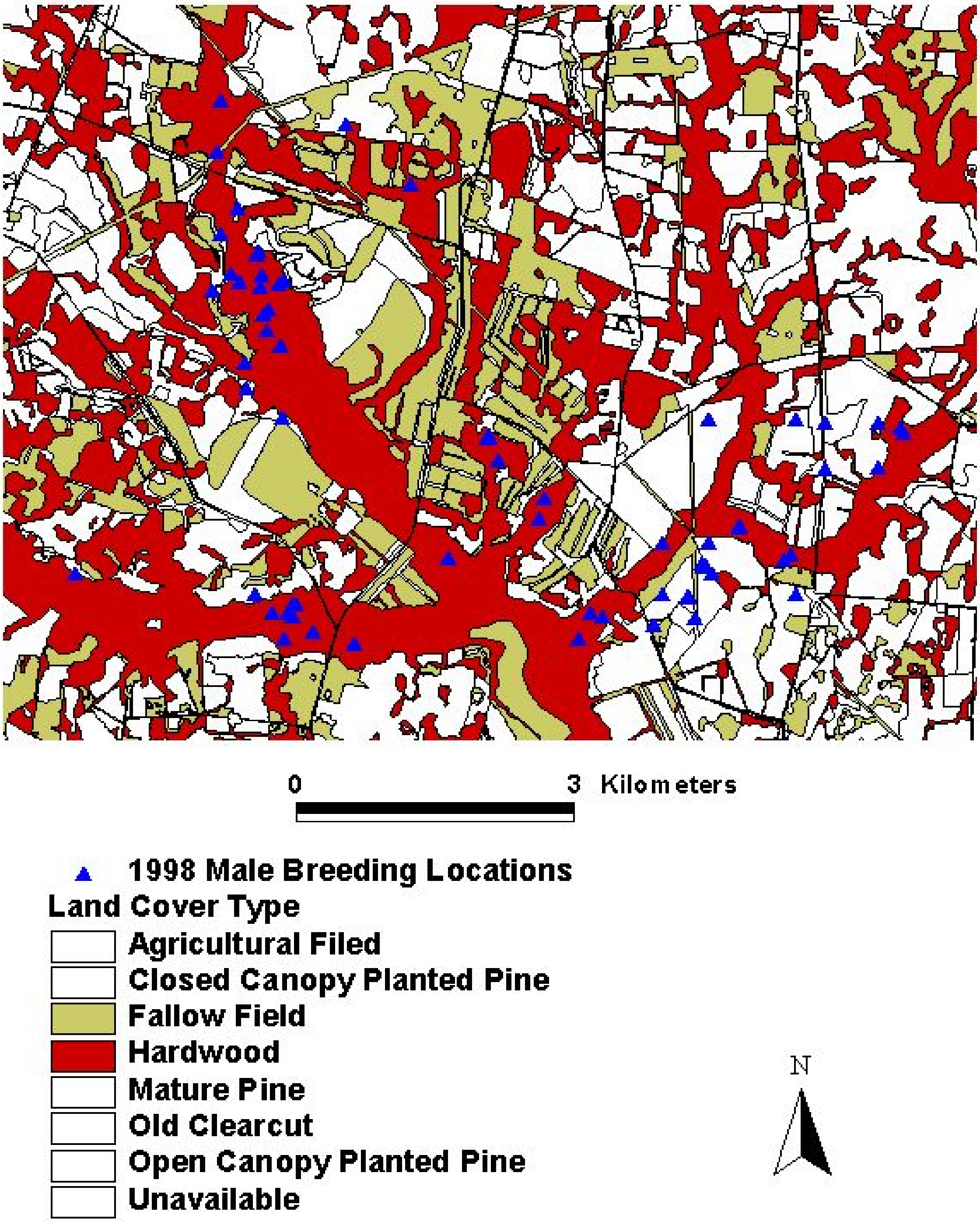
Table 4.6. Frequency with which possible predictor variables occurred within models accepted based on corrected Akaike's Information Criteria (AICc; Burnham and Anderson 1998) for eastern wild turkey and random locations (1998-1999), Di-Lane study area, Burke County, Georgia, USA. Only variables occurring in at least one male or female season with a frequency $33% are shown.

	Frequency (%) of predictor variable[a] in accepted models									
Sex and season	Hwd	OCC	Ag_MP	Ag_CPP	CPP_Fld	CPP_Hwd	CPP_MP	Fld_Hwd	Fld_MP	# of models
Female breeding[b]	75.0		25.0							4
Female post-incubation (successful nesters)[b]	50.0		33.3	33.3						6
Female post-incubation (unsuccessful nesters)	100	33.3		33.3						3
Male breeding		33.3	33.3		66.7	33.3		100	33.3	3
Male post-breeding[b]	36.4				9.1	9.1	36.4			11

[a] Descriptions for predictor variables can be found in Table 4.2.

[b] Intercept only model either had the lowest AICc score or was within 2 AICc scores of the best model, and was included in calculating the number of models.

Figure 4.1. Graphic example of the high affinity male eastern wild turkeys demonstrate for large hardwood tracts. Locations are from the 1998 male breeding season in the Di-Lane study area. Some locations also occurred in the fallow field land cover type but actual locations were distributed farther from the hardwood-fallow field edge border than random locations. The Di-Lane study area was located in Burke County, Georgia, USA.


0
3 Kilometers
1998 Male Breeding Locations
Land Cover Type
Agricultural Filed
Closed Canopy Planted Pine
Fallow Field
Hardwood
Mature Pine
Old Clearcut
Open Canopy Planted Pine
Unavailable
N

CHAPTER 5

SATELLITE REMOTE SENSING AND A SPATIAL HABITAT MODEL ACCURATELY MAP POTENTIAL NESTING HABITAT FOR EASTERN WILD TURKEY IN AN AGRICULTURAL/SILVICULTURAL LANDSCAPE[1]

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[1] White, C. G., H. J-H. Whiffen, S. H. Schweitzer, and J. J. Morgan. To be submitted to the Wildlife Society Bulletin.

ABSTRACT: We report on the application of a 1-variable spatial model that predicted the locations of eastern wild turkey (*Meleagris gallopavo silvestris*) nesting sites in Burke County, Georgia. The original model was developed using spatial variables acquired from a vector land coverage digitized from geo-rectified aerial photos. The creation of this vector spatial database for the 17,513 ha study area required >240 hours of digitizing and error checking. We investigated the ability of rasterized spatial variables, quantified from satellite imagery using geographic information systems (GIS), to accurately populate the same spatial model in a timelier manner. We classified both leaf on and leaf off reflectance data captured by Landsat 5 Thematic Mapper (L5TM) into 3 land cover classes (crop and other tilled lands, fallow fields, and other) to produce the spatial data required by the model. We compared the predictive results of the model when using satellite data to the predictive results of the model when using vector data. The ability of the model to discriminate nesting sites from random sites using satellite data was almost equal to model results using original vector data (73.7 % vs. 79.0 %). We present the methods used to classify satellite data and populate the spatial model. Further we report the relative time needed to develop the vector GIS coverage and the raster GIS coverage. If the time, and, therefore, the cost, required to generate the spatial data required by the model is reduced, the predictive model can efficiently project turkey nesting potential throughout the Upper Coastal Plain of Georgia. The ability to quickly populate a highly-predictive model should help land managers efficiently distinguish those areas under their management with high nesting potential for eastern wild turkey and to monitor other areas as implemented land management strategies improve habitat for nesting turkeys.

INTRODUCTION

The interspersion of fallow fields, hardwood stands, pine plantations, and croplands, commonly found in the southeastern United States creates the landscape mosaic of habitat types in which wildlife live. Since the inception of the Conservation Reserve Program (CRP) in 1985, >830,200 ha of farmland have been converted to tree plantings (mostly pine) in the Southeast (Farm Service Agency 1997). The conversion of cropland to pine plantings is affecting the landscape mosaic. Allen (1993) reported that the establishment of pine plantings under the CRP might have eliminated thousands of acres of high-quality nesting, brood rearing, and foraging habitat in the Southeast. However, little work has been done to evaluate the effects of the changing landscape mosaic on wildlife use and movements.

Although the eastern wild turkey (*Meleagris gallopavo silvestris*) is adaptable and has flourished in the Southeast, the reproductive response (i.e., nesting behavior) of wild turkey within a habitat mosaic containing CRP pine plantings is of concern. Morgan's (2000) review of the literature found a mixed response of eastern wild turkey populations to pine plantings. The quality of nesting habitat and resulting nesting success is not well known for these habitat types. Thus, we investigated document wild turkey nesting behavior within fragmented habitats that included current CRP pine plantings.

Current landscape level techniques used by wildlife researchers to assess the effects of habitat fragmentation on wildlife include analysis options provided by geographic information systems (GIS). Roseberry et al. (1994) assessed the potential impact of converting agriculture lands to CRP plantings in the Midwest on northern bobwhite (*Colinus virginianus*) using remote sensing, GIS, and habitat modeling. Ripple et al. (1997) used GIS to study the landscape composition and pattern around northern spotted owl (*Strix occidentalis caurina*) nests in southwestern Oregon. Recently, Merrill et al. (1999) used GIS to analyze land-use patterns surrounding greater prairie-chicken (*Tympanuchus cupido pinnatus*) leks in northwestern Minnesota.

Other wildlife researchers have incorporated landscape metrics into their studies to evaluate the effect of patch (a single homogeneous landscape unit), class (set of similar patches), and landscape (mosaic of interacting patch types) characteristics on wildlife phenomena (McGarigal and Marks 1995). Heinen and Cross (1983) described a method of measuring habitat type interspersion, juxtaposition, and spatial diversity on cover-type maps to assess quality of wildlife habitat. Robinson et al. (1995) used FRAGSTATS (McGarigal and Marks 1995) software to calculate the percentage of forest cover, forest interior, and forest patch sizes in 9 Midwestern states, when studying the regional forest fragmentation and the nesting success of migratory birds. Roseberry and Sudkamp (1998) used classified satellite imagery in combination with FRAGSTATS software to assess the suitability of landscapes for northern bobwhite.

Current literature revealed a trend to use GIS, remote sensing, landscape variables, and/or multivariate statistics to evaluate wildlife habitat cover conditions (Hill and Bleich 1999, Johnson et al. 1999, Bogaert et al. 2000, Fox et al. 2000). For example, Penhollow and Stauffer (2000) used stepwise multiple regression and stepwise logistic regression to determine the large-scale habitat measures associated with the community performance of neotropical migratory birds. To generate habitat metrics, they used GIS coverages within the vector version of FRAGSTATS. Miller et al. (2000) modeled habitat selection for eastern wild turkeys in Mississippi using vector GIS coverages generated from color infrared aerial photographs and 1:24,000 U.S. Geological Survey 7.5 min quadrangles, and logistic regression.

Morgan (2000) used GIS, logistic regression, and FRAGSTATS*ARC™ (Pacific Meridian Resources 2000) to quantify landscape level influences on nest site selection by wild turkeys. The goal of his research was to develop a simple, yet robust model that accurately predicted nesting locations in a large geographic area. For Morgan's (2000) model, >240 hours (C. G. White, University of Georgia, unpublished data) were spent computer-digitizing all land cover types as vector polygons ($n \geq 1,764$) for a spatial extent of 174.4 km^2 that encompassed both the Alexander and Di-Lane Plantation Wildlife Management Areas (WMA), Georgia. Thirty-four nest sites from 29 radio-marked hens and 34 randomly selected sites were each buffered with a 250-m radii. Class and landscape metrics were calculated using FRAGSTATS*ARC. Using the digitized habitat coverage for Alexander and Di-Lane Plantation WMAs, a cross-validation test (C. T. Moore, University of Georgia, unpublished SAS cross-validation macro) demonstrated that the percentage of fallow field generated a powerful, 1-variable model that accurately predicted 79.0% of nest sites selected (Morgan 2000). We examined the 1-variable model developed by Morgan (2000) for spatial patterns. The difference between randomly selected and actual nest sites was due to the larger percentage of fallow field in the nest site buffers relative to the randomly selected site buffers (Fig. 5.1).

Morgan's (2000) model provides a land manager with an effective means of monitoring wild turkey nesting site availability across a southeastern landscape. However, the time required to digitize and maintain the vector coverages for large landscapes hinders model use. Managers need a time-efficient and inexpensive method to populate models like this nesting habitat model. Obtaining spatial variables from satellite imagery can be more time efficient, but the conversion alters the variables generated. For example, Bettinger et al. (1996) found that measures were sensitive to the grid cell size used in a vector-raster conversion process, and found that polygon areas, were significantly modified when converted from vector-raster-vector using cells girded at both 20 m and 30 m resolutions. Therefore, our goal was to determine whether reflectance data in a 30-m raster format could accurately produce the spatial variables required to populate a spatial model that was created using vector polygons digitized at the 1:3,000 scale.

We compared the percentage of fallow field in each buffer as determined from the vector data and as calculated from the classified raster data. We also compared the predictive power of the model populated with spatial data from the digitized, vector coverage with the classified, raster coverage. We report our methods for making these comparisons between raster and vector data to encourage the use of such spatial models by land managers.

STUDY AREA

The Alexander WMA was a 555-ha tract in the Upper Coastal Plain physiographic region, Burke County, Georgia, that, until 1988, was privately owned and planted primarily in row crops or used as pasture. In 1988, 380 ha of cropland was planted in loblolly pines (*Pinus taeda*) following CRP planting guidelines (1,793 trees/ha). The property was left unmanaged after 1988 and was acquired by the Georgia Department of Natural Resources (GDNR) in November 1997. As of 1999, the

Alexander WMA included 166 ha of hardwoods and 9 ha of fallow fields, in addition to the 380 ha of planted pine. Movements of radio-marked turkeys beyond the Alexander WMA boundary extended the spatial extent of this study area to >3,861 ha.

The second area included in the modeling study was the 3,278-ha Di-Lane Plantation WMA. In 1986, 286 ha were enrolled in the CRP and planted to loblolly pine at 1,793 trees/ha. The U.S. Army Corps of Engineers purchased this WMA in 1992 as mitigation for lands flooded by Lake Russell and the GDNR began managing the property primarily for northern bobwhite. Several habitat types were found on Di-Lane including 1,666 ha of mixed pine-hardwoods, 849 ha of fallow fields, 497 ha of planted pines. Movement of radio-marked turkeys beyond the Di-Lane WMA boundary, extended the spatial extent of this study area to >13,574 ha.

METHODS

Generating the spatial variables for the model

Habitat types located on Alexander, Di-Lane Plantation, and the surrounding areas were digitized at a scale ≥1:3,000 (units = meters), referencing U.S. Geological Survey 1993 Digital Orthophoto Quarter Quadrangles (DOQQ) with a root mean square error (RMSE) of ≤1.6 m in ESRI™ ArcView (Environmental Systems Research Institute 1999*b*). Digitized habitat types included active agricultural fields, clearcuts, closed-canopy planted pine, fallow fields, hardwoods, mature pine, open-canopy planted pine, pecan orchards, residential areas, rights-of-way, roads, and bodies of water (Table 5.1). Our knowledge of the area was used to correctly classify, modify, and update the 1993 landscape polygons to represent the 1998 and 1999 landscapes. Further, we carefully verified the accuracy of the spatial coverages while acquiring and recording turkey movements in the field.

From January – March 1998 and 1999, eastern wild turkeys were captured, banded, and radio-marked (University of Georgia IACUC Protocol No. A960216C2). Incubating hens were identified by inactive radio signals on consecutive days and nest sites were located by encircling hens at a range of 30-50 m (Morgan 2000). Nest bowl sites were later recorded in Universal Transverse Mercator (UTM) coordinates in Zone 17 North using the North American Datum 1983 (NAD83), with a Trimble™ GeoExplorer II hand-held global positioning system (GPS) receiver (Trimble Navigation Ltd., Sunnyvale, California). Turkey nest coordinates were differentially corrected using data from 1 of 3 nearby base stations (Charleston, SC; Columbia, SC; New Ellenton, SC) using Trimble Pathfinder Office software (Trimble Navigation Ltd., Sunnyvale, CA) and then imported into ArcView as dbase files (✻.dbf).

Random points were generated using a uniform random distribution over the extent of the digitized study areas, in proportion to the number of nests in each WMA, using the Animal Movement extension (Hooge and Eichenlaub 1999) in ArcView. Both turkey nest locations and randomly selected sites were buffered at a radius of 250-m forming a 19.5-ha area around each point. Habitat types within each buffer were spatially extracted and used to populate the 1-variable, logistic regression model that predicted nesting locations (Morgan 2000; Fig. 5.2). A Monte Carlo cross-validation test was used to determine the predictive capability of the model. The cross-validation test used, split the available data records into 2 subsets: a model-building subset and a validating subset. The cross-validation procedure was iterated ≥1,000 times, with random splitting of data records between the model building and validating subsets (C. T. Moore, University of Georgia, personal communication). The mean percentage of nest sites, using this cross-validation test, correctly classified by the 1-variable model was 79.0% (Morgan 2000).

Classification of satellite imagery

Sensors on the Landsat 5 Thematic Mapper (L5TM) satellite measured the quantity of solar energy passively reflected from features on Earth's surface in several wavelengths. The satellite stored these data in a matrix form organized into 7 bands. The bands used for this study (Band 1–5 and 7) ranged in wavelength from the visible (0.45 μm) to the mid-infrared (2.35 μm). These bands had a spatial resolution (cell size) of 30 m x 30 m.

Two Landsat 5 Thematic Mapper (L5TM) satellite scenes (leaf-on and leaf-off), each with a spatial extent of approximately 45,900 km^2, were acquired from the Natural Resource Spatial Analysis Laboratory (NARSAL), University of Georgia, Athens, GA, USA. The satellite scenes were referenced by path and row numbers corresponding to the L5TM sun-synchronous orbit (Lillesand and Kiefer 1994; Fig. 5.3). The 2 L5TM scenes used in this study came from Path 17, Row 37. The leaf-off data were collected on January 1998; leaf-on data were collected on July 1998. To reduce the file size and speed software processing, the original satellite scenes were clipped down to a 730 km^2 area spatially coincident with the study areas (Fig. 5.4).

Unsupervised classification. A cursory inspection of the L5TM data overlaid by the digitized land cover polygons (HABITAT.SHP) indicated that there could be 2 distinct spectral signatures within a single, digitized land cover class. Specifically, in

HABITAT.SHP, all fallow fields, that were being managed as pasture and hayfields or were left unmanaged, were coded as fallow field. However, the recorded reflectance data within managed pastures and hayfields was different than the reflectance data within the unmanaged/unattended fields. We were concerned that the fallow fields classified using the supervised algorithm would subdivide the fallow field land class into 2 classes (Type A: inactive fields; and Type B: hay and pasture fields). To assess whether this within-class spectral difference was detectable, we ran an unsupervised classification using Imagine (ERDAS 1999*b*) and a maximum of 20 clusters. The convergence threshold, which is the maximum percentage of cells whose values are allowed to be unchanged between iterations, was set to 0.95.

Unsupervised classification does not use training site data as the basis for classification. Instead the reflectance data for each band in each cell in an image is examined and iteratively aggregated into the stated number of classes based on the natural spectral clusters present. The resulting classes are then compared to known reference sites to identify what land cover type each class represents (Lillesand and Kiefer 1994). For the comparison to reference sites, several digitized polygons of Type A were selected to make a new coverage called POLYGON1; several digitized polygons of Type B were used to make POLYGON2. In each new coverage, fallow field polygons were coded 1; all other regions of the spatial extent were coded 0. These 2 polygon coverages (POLYGON1 and POLYGON2) were converted to raster (POLYGON_GRID1 and POLYGON_GRID2, respectively) (Fig. 5.4).

To isolate the spectral signatures for Type A and Type B fallow fields, the unsupervised classified coverage (UNSUPER_GRID) was multiplied separately with

POLYGON1_GRID and POLYGON2_GRID, producing coverages containing only Type A signatures (FALLOW1) or Type B signatures (FALLOW2) from UNSUPER_GRID (Fig. 5.4).

Supervised classification. The key difference between an unsupervised classification and a supervised classification is the order in which a signature is assigned to a land cover class. In an unsupervised classification, spectrally similar cells are grouped together and then matched to a land cover class. In a supervised classification, pre-defined class categories defined by training sites are used to define class signatures and quantify signature separability before the classification is done (Lillesand and Kiefer 1994). Training sites are those locations in which the land cover type is known through a precise field survey. From these locations, the reflectance signatures for the pertinent land cover types are determined. A land cover signature is just like a person's signature; each is composed of several letters or traits that, in combination, uniquely identify 1 person or, in this case, 1 type of land cover.

For this study, several training sites for each land cover type of interest (i.e., fallow field, active agriculture, and other) were isolated in HABITAT.SHP and converted into a signature file. Then each L5TM scene (leaf-on and leaf-off) was classified into the land cover classes following common supervised classification procedures (Fig. 5.5) outlined by Lillesand and Kiefer (1994).

To analyze the quality of the leaf-on and –off signatures we compared the signature histograms, and reviewed the contingency matrix and signature separation. A contingency matrix is a matrix that shows how well satellite data from original training sites were classified by signatures developed from training sites (ERDAS 1999a). Signature separation is a measure of the multivariate distance between signatures and is important when classifying satellite data. The signatures must be far enough apart, in multivariate space, so each class is distinct and class confusion during the supervised classification process is minimal.

In a supervised classification, each cell of raw data in a scene is compared to the given signatures according to a specified decision rule and assigned to the signature it most closely resembles in multivariate space. Once we were satisfied with the quality of the signatures defined by the training sites, we ran the supervised classification algorithm on a 12-band composite twice using the fallow field and active agriculture leaf-off signatures to produce 1 raster coverage (LANDCOVER1), and the fallow field and active agriculture leaf-on signatures to produce a second raster coverage (LANDCOVER2; Fig. 5.5). In each case we used the parallelepiped non-parametric (objects in feature space) rule and specified that the "cell-to-signature" match included all cells with data that fell within 2 standard deviations of the defined signature mean (decision region). In the event that a signature fell outside of either the fallow field or active agriculture decision region, the cell was assigned to the "other" land cover class: a class designated to contain all other land cover types except fallow field and active agriculture. For those cells that fell into the decision region of both signatures simultaneously, the maximum likelihood parametric (objects in statistical space) rule was used.

We were fortunate to have both the leaf-on and leaf-off L5TM scenes available for this study, but natural resource managers will not always have both scenes available to them. To help inform natural resource managers regarding the more informative scene, we evaluated the classification quality of the leaf-on signatures relative to the leaf-off signatures to determine which season of satellite data produced the more accurate land cover map.

Comparison of classified satellite habitat coverage with digitized habitat coverage

To compare the habitat class match between the digitized habitat coverage (HABITATS.SHP) and the most accurate supervised classified habitat coverage (LANDCLASS) we converted the polygons representing fallow fields and active agricultural lands in HABITAT.SHP to a raster coverage with a cell size and spatial extent equal to LANDCLASS (Fig. 5.5). We reclassed this new raster coverage (DIGI_CLASS) so the cell values for the 2 important land cover classes (fallow field and active agriculture) were equal to the cell values for those classes in LANDCLASS. We used the MapCalculator function in ArcView to subtract LANDCLASS from DIGI_CLASS (Fig. 5.5). Data exported to Microsoft™ Excel from the resulting coverage (MATCH) allowed us to spatially and graphically identify how well the classified habitat coverage matched the digitized image.

Modeling using classified remote data

In order to determine how well the model, which was populated using 30-m data from a classified habitat coverage, duplicated the results when the same model was populated using data from a 1:3,000 digitized habitat coverage, we clipped the reclassed, classified habitat coverage (LANDCLASS) using "gridclip" (ArcInfo) and the buffered (19.5-ha area) nest and randomly selected site polygons (NEST_HAB and RAND_HAB, respectively; Fig. 5.5). Output included a text file that contained the number of cells classified as fallow field, active agriculture, and “other” for each buffered site. The number of fallow field cells per buffer was converted to percent fallow field$_{classified}$ per buffer and these per buffer percentages were entered into the cross-validation test to determine the predicted percentage of wild turkey nests. Commission and omission errors were calculated with an additional SAS macro (C. T. Moore, University of Georgia, unpublished SAS AIC score macro).

RESULTS

It took <100 hours of computer time to prepare the L5TM scenes, identify the optimal training sites, refine the signatures, and complete a supervised classification of both the leaf-on and leaf-off data. The spatial extent covered by the largest L5TM scene (leaf-off) was 45,903.5 km^2. Once the scene was clipped to reduce storage space required and to increase computing speed, it had a spatial extent of 726.0 km^2.

Signature quality

The field and agriculture signatures for both the leaf-on and –off data had dissimilar means (Fig. 5.6). The convergence matrix output reported that the leaf-on signatures correctly classified 99.3% of the fallow field training site cells and 100% of the active agriculture training site cells. The leaf-off signatures correctly classified 99.2% of fallow field cells and 98.9% of active agriculture cells. The signatures in each data set (leaf-on and leaf-off) had maximum separation (ERDAS 1999*a*).

The unsupervised classification identified 2 distinct signatures on the 12-band composite image of fallow field areas (Fig. 5.7). Cell values in FALLOW1 indicated that the subset of fallow fields represented in this coverage (Type A) had a signature peaking at 12 with most values between 10-12. Cell values in FALLOW2 indicated that the subset of fallow fields represented in this coverage (Type B) had a signature peaking at 15 with some cell values at 10, 12-14.

Classification quality

For each buffer, the percentage of fallow field$_{classified}$ was compared to the percentage of fallow field$_{digitized}$. Although the fallow field proportions in the buffered area surrounding the actual nesting sites differed slightly between fallow field$_{classified}$ and fallow field$_{digitized}$, they were very similar (Fig. 5.8). The fallow field proportions in the buffered area surrounding the randomly selected sites showed a wide separation between fallow field$_{classified}$ and fallow field$_{digitized}$ at the lowest percentages of fallow field but the overall trends of fallow field$_{digitized}$ were simulated by fallow field$_{classified}$. The overall numerical and graphical trends of percentage of fallow field within the buffers demonstrated the similarity between fallow field$_{classified}$ and fallow field$_{digitized.}$

Modeling quality

Cross-validation of the model populated with the spatial data from L5TM resulted in a wild turkey nest prediction rate of 73.7%. Turkey nest site selection was predicted 10.3% of the time when a nest site was not detected (commission error). Turkey nest site was detected 14.7% of the time where no nest was predicted (omission error).

DISCUSSION

The differences between fallow field and active agriculture signatures (for both leaf-on and leaf-off) used for the supervised classification were very distinguishable and the classified image accurately represented the location of active agriculture and fallow fields within the study area. Applying an unsupervised classification method allowed us to distinguish differences within the fallow field signature, indicating that it would be possible to more narrowly define and identify unique subset of cover types within the fallow field habitat cover type if this information had value for the land manager. We did not explore this, beyond presenting the method on how to do it, since we needed to only identify all fallow fields as 1 cover type. However, the procedure could be used to analyze unique subsets of a cover type(s) for preferential use by a wildlife species within the cover type(s).

The comparison of the digitized habitat coverage to the supervised classified habitat coverage was facilitated by using the Map Calculator function in ArcView (Environmental Systems Research Institute 1999*b*). Our results indicated a good match between the digitized land cover data and the classified land cover data. As we emphasized earlier (Fig. 5.1) for the Morgan (2000) model, the percentage of fallow field was greater and occurred in more buffers around the nest sites relative to the buffers around the randomly selected sites and appeared to be the key to the model's predictive power. We classified a L5TM scene using an unbiased and easy to follow methodology. The classified data from the satellite approximated (Fig. 5.8) the general trend of the digitized data and worked well with the Morgan (2000) model.

Another benefit of this comparison between HABITAT.SHP and LANDCLASS was the revelation of coding errors in HABITAT.SHP. There was a noticeable difference between the total percentage of fallow field in HABITAT.SHP and the total percentage of fallow field in LANDCLASS. This led to the discovery that certain areas in our study area that had received clearcuts <5 years ago were mistakenly coded as old clearcuts in HABITAT.SHP but reflectively matched the fallow field signature (Table 5.1). This, then, served as a check for errors in the coding of polygons in the digitized, vector habitat coverages (HABITAT.SHP). [Note that the buffered nest and randomly selected sites had little or no mis-labeled clearcuts within their boundaries.]

The amount of time it took to digitize from the DOQQs the entire study area, encompassing all buffered eastern wild turkey nests and randomly selected sites (13,574 ha), was more than twice the time it took to classify the L5TM data (72,599 ha). We were able to compare only the amount of computer time it took because our knowledge of the training sites used in the supervised classification was acquired while field checking HABITAT.SHP. However, it is fair to conclude that time spent identifying training sites in the field would be equivalent to or less than the time spent acquiring knowledge of an area for digitizing and ground truthing areas difficult to access from the aerial photos. In summary, one can accurately map the land cover classes necessary to populate the Morgan (2000) model for a larger area using satellite data in substantially less time than it takes to digitize land cover polygons for a much smaller area. The larger the area, the more digitizing time required; the more digitizing, the greater the cost in labor and tedium.

Although Bettinger et al. (1996) found that many landscape measures were sensitive to grid cell size, we were able to predict nest site selection with the Morgan (2000) model using 30-m raster data with an accuracy very similar to the modeling results using 1:3,000 vector data. Readers should be cautioned that the prediction rate reported by Morgan (2000) using digitized data was untested on an independent data set.

We have presented a set of techniques that can be used to incorporate data from satellite images into a spatial habitat model. Our work outlines techniques that can be used to validate a model over a large geographical area without involving an enormous amount of time digitizing large geographical areas. Further, it provides a methodology for other researchers to follow who are interested in testing habitat models, originally populated using vector GIS data, with raster GIS data. Adaptation of the methods and evaluation procedures presented here may be needed depending on the metrics used in the habitat model. At this time, some measures may not be easily converted between vector and raster due to their shape, limitations in computing technology, or differences in data resolution.

MANAGEMENT IMPLICATIONS

We have presented the use of a model that accurately predicts the spatial distribution of eastern wild turkey hen nests. We believe in the adage that if you are going to manage for something manage it where you are going to be most successful. Use of the Morgan (2000) model, populated with raster GIS data, will help managers locate quality nesting sites for wild turkeys. It will be easiest to maximize habitat quality for nesting turkeys in areas where many quality nesting sites already occur. In this manner, use of this model can help managers locate areas of their land base to prioritize for nesting habitat improvements so the effort will make the biggest difference on the turkey population.

Many wildlife managers are using spatial data in their management activities including monitoring and evaluating habitat, analyzing radio telemetry data, characterizing the spatial structure of habitats, and modeling the spatial distribution of species (Koeln et al. 1994). We understand the reservations that wildlife managers may have about applying this model to their own management area. It has been our experience that modelers rarely validate models of spatial distribution of species built for 1 geographic region with separate data from the same location. Or, managers are encouraged to use a model but never informed by the modelers as to how to acquire the data required to populate the model for a different spatial extent. Or, managers may not have the type (vector or raster) of spatial data used to initially build the model. All of these constraints hinder the application of published models to real world management issues. To assist those managers who want to use models of spatial distributions we have delineated, in plain English, the steps required including how to generate a nesting habitat model using GIS, classify satellite imagery, compare classified remote images to digitized habitat maps, and model nesting habitat using classified imagery.

Before managers engage in the use of GIS for habitat mapping and wildlife management, they should keep in mind that the form of the data also directs the ability to classify habitat types and the time involved in classifying. Vector data allows for patch by patch identification but requires more effort and time the larger the area gets. Raster data have a built in adaptability for mass identification of a cover type and become more time efficient the larger the area becomes. Generally, satellite data coverage for an area can be acquired yearly and often seasonally within a year. This is an important consideration if the land cover the manager is interested in is subjected to the rapid changes typically noted in active agricultural areas.

Note. The computer used for this study was a Pentium III running Microsoft™ Windows NT, with a 600 megahertz processor, 256 Mb of RAM, 32 Mb graphic card, and a 10 Gb hard drive. This computer was more than adequate for the software used in our research. Managers should consult software vendors for software costs and minimum computer requirements needed to operate specific software.

Acknowledgements. We thank R. T. "Tripp" Lowe for help with the L5TM scenes and preparing the ARC/INFO GridClip AML. C. T. Moore provided statistical guidance and SAS macros used to obtain model's mean percent correctly classified, and to obtain commission and omission errors. Dr. E. A. Kramer and the MRLC Consortium provided the L5TM scene data, and C. E. Eckley provided the DOQQs. Funding was provided by the National Wild Turkey Federation through funding by an anonymous donor and coordinated through The National Fish and Wildlife Foundation. Additional support was provided by the Georgia Department of Natural Resources (GA DNR), Wildlife Resources Division, Game Management Section and the University of Georgia (UGA), Daniel B. Warnell School of Forest Resources.

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Table 5.1. Habitat cover types and their composition, defined for digitizing Alexander and Di-Lane Plantation Wildlife Management Areas, Burke County, Georgia.

Habitat type	Composition
Active agriculture	Cultivated fields, <1 year old clearcuts
Clearcuts	Stand composed of dense regeneration 5-15 years old
Closed-canopy planted pine	Managed planted pine stands at canopy closure
Fallow fields	Fallow areas, mowed areas, 1-4 year old clearcuts
Hardwoods	Stand composed of 50% hardwoods >15 years old
Mature pine	Stand composed of >50% pines >20 years old
Open-canopy planted pine	Thinned, managed pine stands, <5 year old planted pine
Pecan orchards	Commercial or maintained pecan trees
Residential areas	Houses or large buildings
Rights-of-way	Areas under maintained power lines
Roads	Major paved or unpaved road with ≥2 lanes
Water	Permanent or semi-permanent open-water ponds

Figure 5.1. Percentage of fallow field differed between the buffer surrounding the actual eastern wild turkey nest sites and the buffer surrounding the randomly selected sites, Burke County, Georgia, 1998-1999.

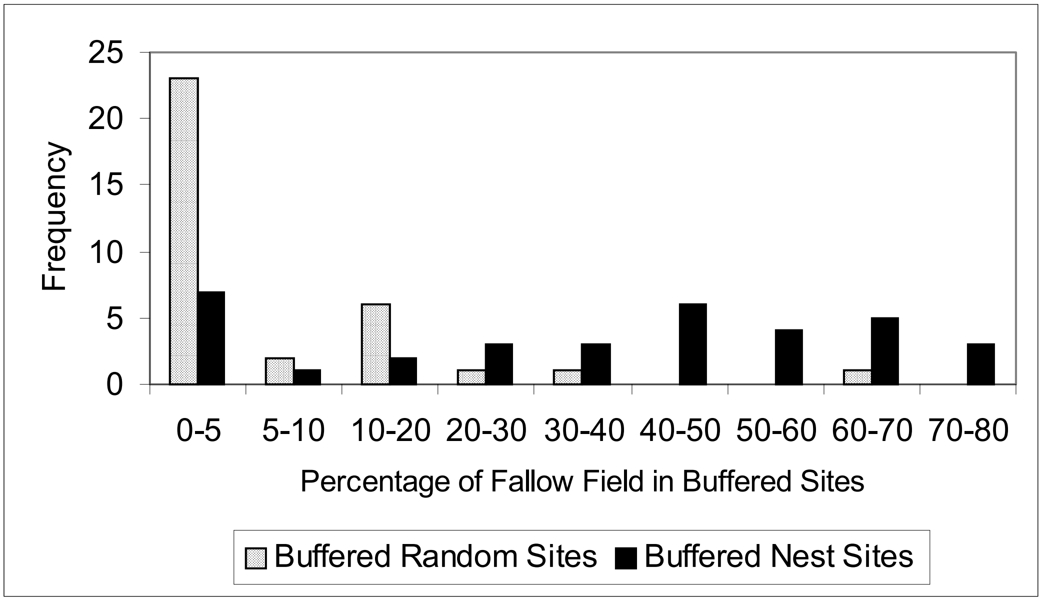
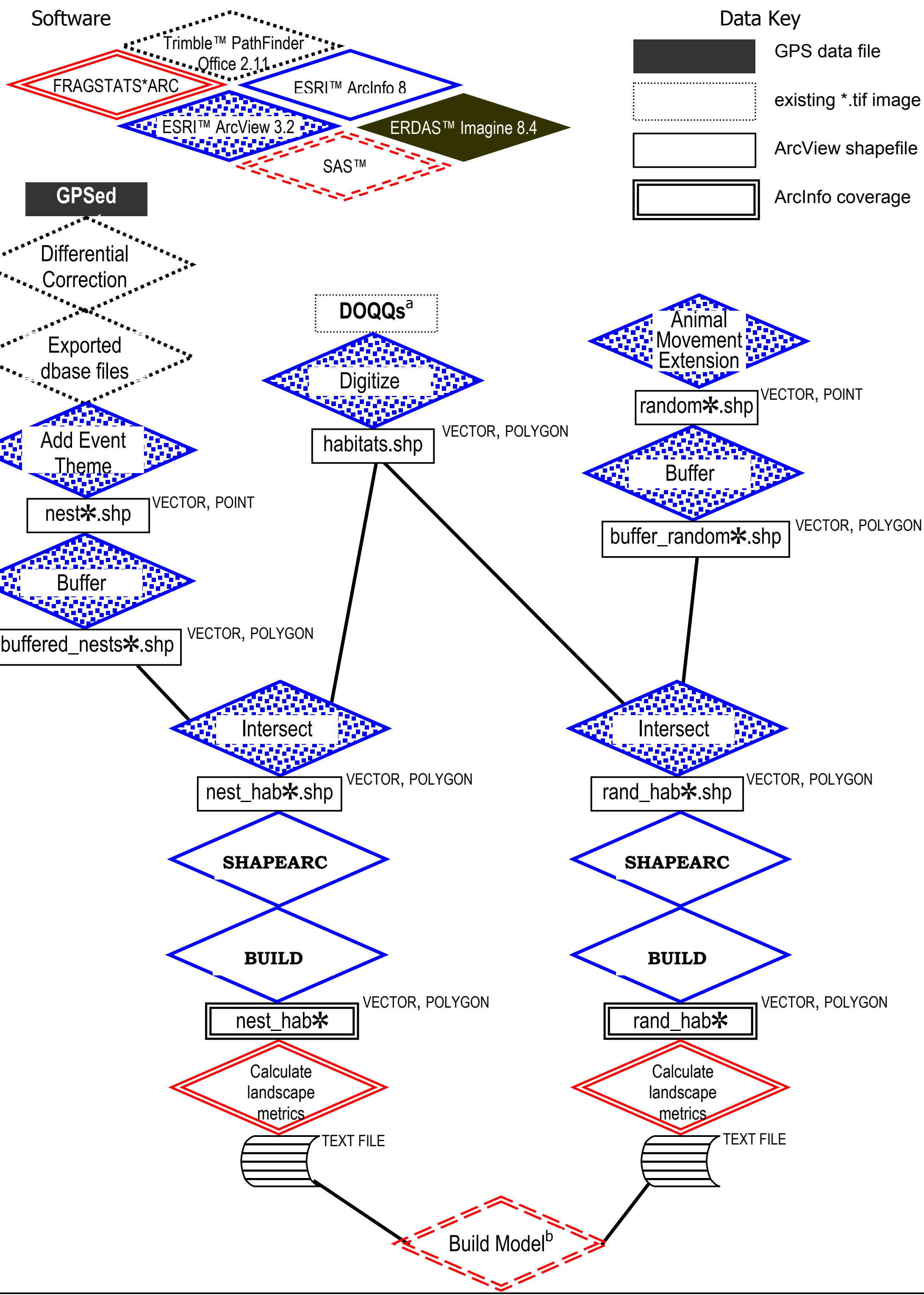

25
20
15
10
5
0
Frequency
0-5
5-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
Percentage of Fallow Field in Buffered Sites
Buffered Random Sites
Buffered Nest Sites

Figure 5.2. Methods used to spatially extract habitat types in buffered turkey nest sites and buffered randomly selected sites. These methods were used by Morgan (2000) to populate a 1-variable, logistic regression model that accurately predicted nesting locations.



a DOQQ (digital ortho-photographic quarter quadrangle): an aerial photograph registered precisely to real world coordinates. The spatial extent of each DOQQ is one-quarter of the spatial extent of a USGS quadrangle map.

b Model formulation was assisted by a SAS cross validation macro written by Clint T. Moore, D.B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602.

Figure 5.3. The 2 Landsat 5 Thematic Mapper (L5TM) scenes used in this study were from Path 17, Row 37. Path and row numbers reference satellite scenes. Multiple scenes from different paths and rows are available for those areas that fall within the overlapping portions of the scenes.

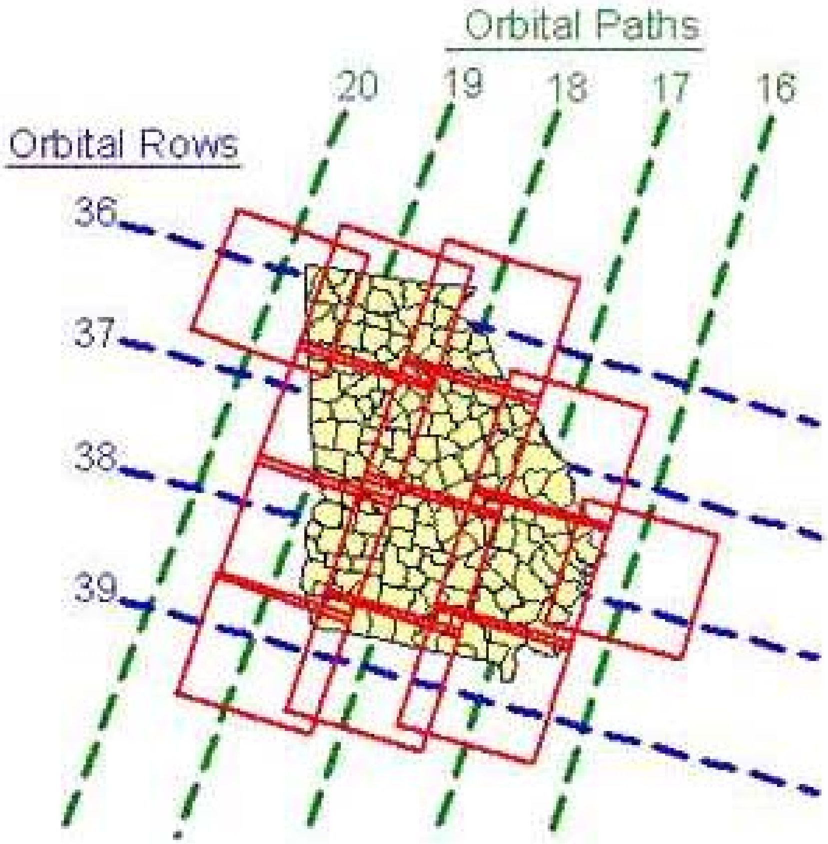

Orbital Paths
20
19
18
17
16
Orbital Rows
36
37
38
39

Figure 5.4. Methods for the unsupervised classification and subsequent assessment of 2 distinct fallow field categories.

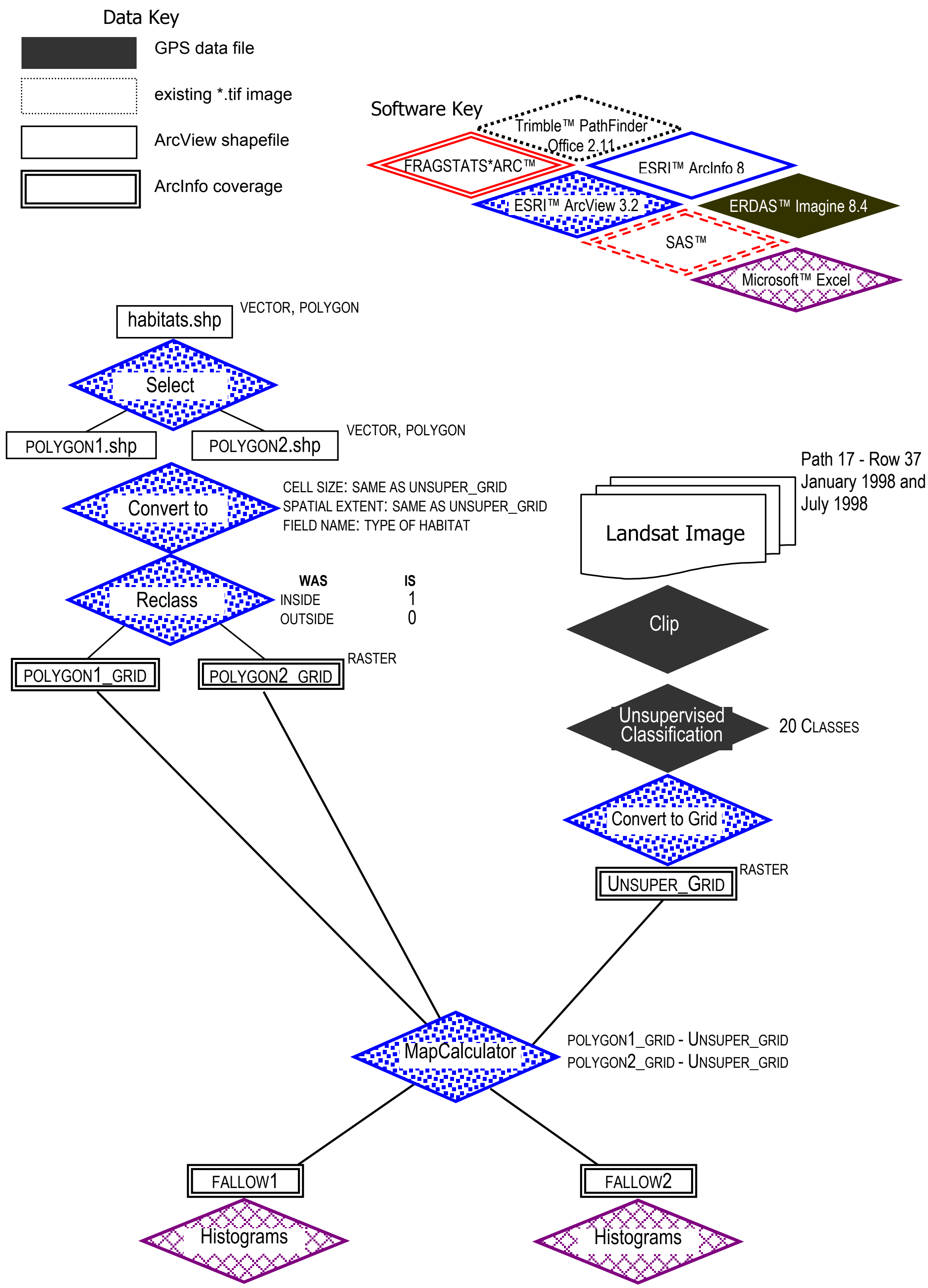
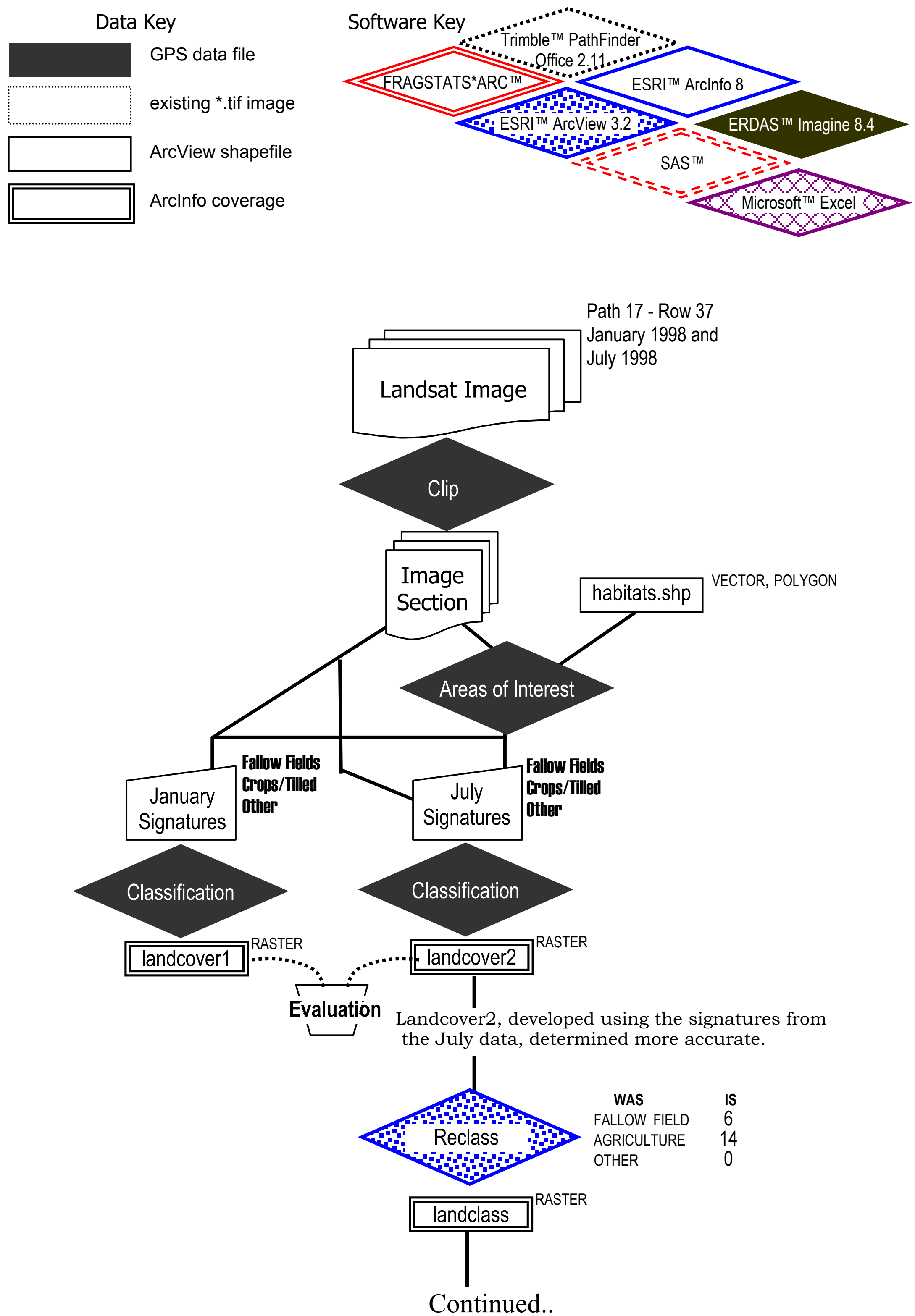
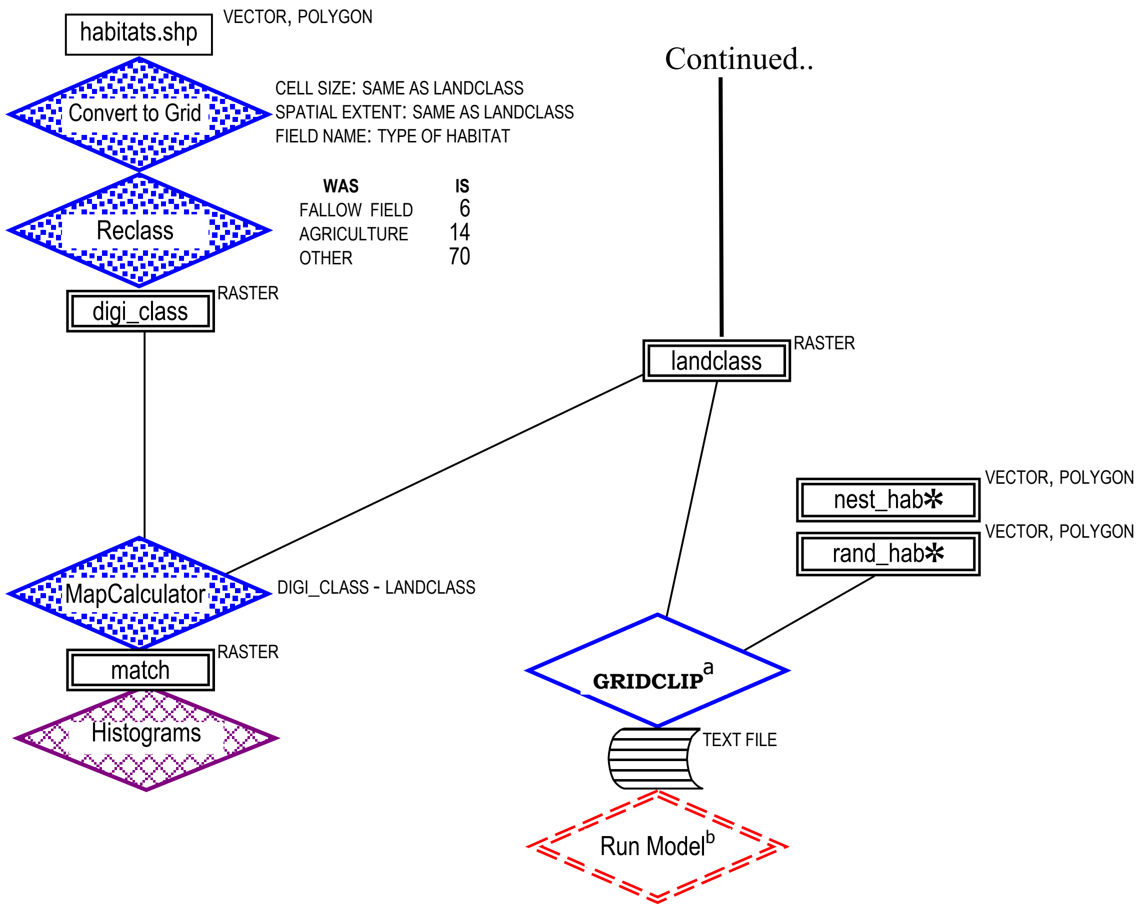

Data Key
GPS data file
existing *.tif image
ArcView shapefile
ArcInfo coverage
Software Key
Trimble™ PathFinder Office 2.11
FRAGSTATS*ARC™
ESRI™ ArcInfo 8
ESRI™ ArcView 3.2
ERDAS™ Imagine 8.4
SAS™
Microsoft™ Excel
habitats.shp
VECTOR, POLYGON
Select
POLYGON1.shp
POLYGON2.shp
VECTOR, POLYGON
Convert to
CELL SIZE: SAME AS UNSUPER_GRID
SPATIAL EXTENT: SAME AS UNSUPER_GRID
FIELD NAME: TYPE OF HABITAT
Reclass
WAS IS
INSIDE 1
OUTSIDE 0
POLYGON1_GRID
POLYGON2_GRID
RASTER
Path 17 - Row 37
January 1998 and
July 1998
Landsat Image
Clip
Unsupervised Classification
20 CLASSES
Convert to Grid
UNSUPER_GRID
RASTER
MapCalculator
POLYGON1_GRID - UNSUPER_GRID
POLYGON2_GRID - UNSUPER_GRID
FALLOW1
FALLOW2
Histograms
Histograms

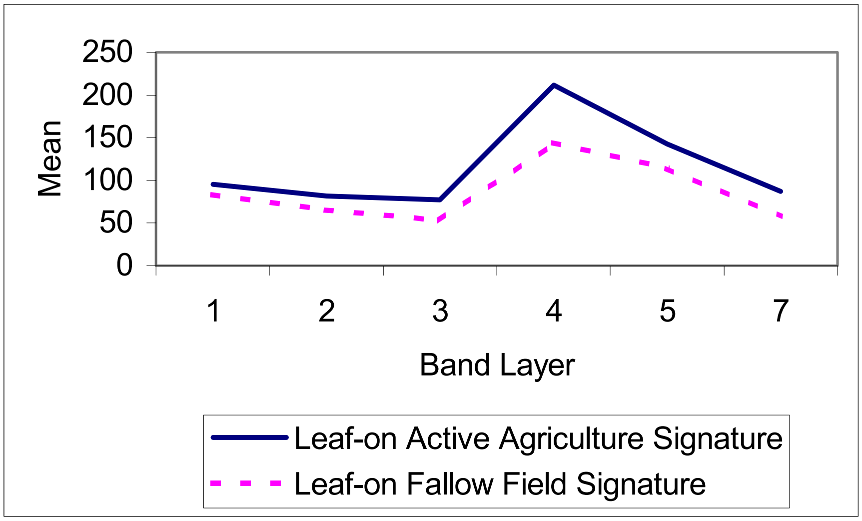
Figure 5.5. Supervised classification of satellite data comparison between the percentage of fallow field$_{classified}$ and fallow field$_{digitized}$, and the subsequent populating of the 1-variable model from Morgan et al. (In review) from raster data was accomplished by following this spatial diagram.


Data Key
GPS data file
existing *.tif image
ArcView shapefile
ArcInfo coverage
Software Key
Trimble™ PathFinder Office 2.11
FRAGSTATS*ARC™
ESRI™ ArcInfo 8
ESRI™ ArcView 3.2
ERDAS™ Imagine 8.4
SAS™
Microsoft™ Excel
Path 17 - Row 37
January 1998 and
July 1998
Landsat Image
Clip
Image Section
habitats.shp
VECTOR, POLYGON
Areas of Interest
January Signatures
Fallow Fields
Crops/Tilled
Other
July Signatures
Fallow Fields
Crops/Tilled
Other
Classification
Classification
landcover1
RASTER
landcover2
RASTER
Evaluation
Landcover2, developed using the signatures from the July data, determined more accurate.
Reclass
WAS
IS
FALLOW FIELD
6
AGRICULTURE
14
OTHER
0
landclass
RASTER
Continued..

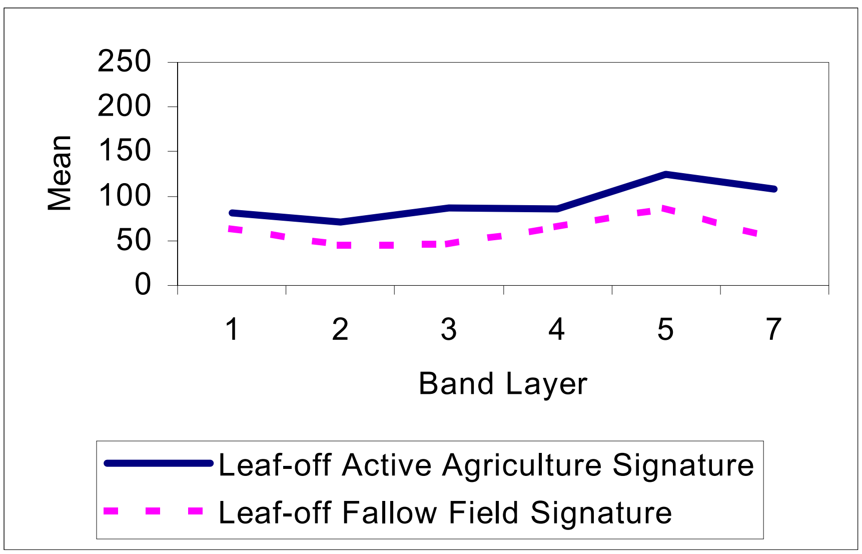


a	The AML for the GRIDCLIP process in ARC/INFO was written by Roger "Tripp" Lowe, SIFR Laboratory Manager, D.B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602.
b	Model formulation was assisted by a SAS cross validation macro written by Clint T. Moore, D.B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602.

Figure 5.6. Mean band layer for the field and agriculture signatures, in both the leaf-on and –off data, had dissimilar means. Although signatures within leaf-on and leaf-off graphically track one another, the substantial difference in means allowed us to accurately classify the satellite data for our study areas in Burke County, Georgia.



Mean
250
200
150
100
50
0
1
2
3
4
5
7
Band Layer
Leaf-on Active Agriculture Signature
Leaf-on Fallow Field Signature



Mean
250
200
150
100
50
0
1
2
3
4
5
7
Band Layer
Leaf-off Active Agriculture Signature
Leaf-off Fallow Field Signature

Figure 5.7. Signatures from the unsupervised classification of the composite (leaf-on and leaf-off scenes) identified 2 distinct fallow field cover types.

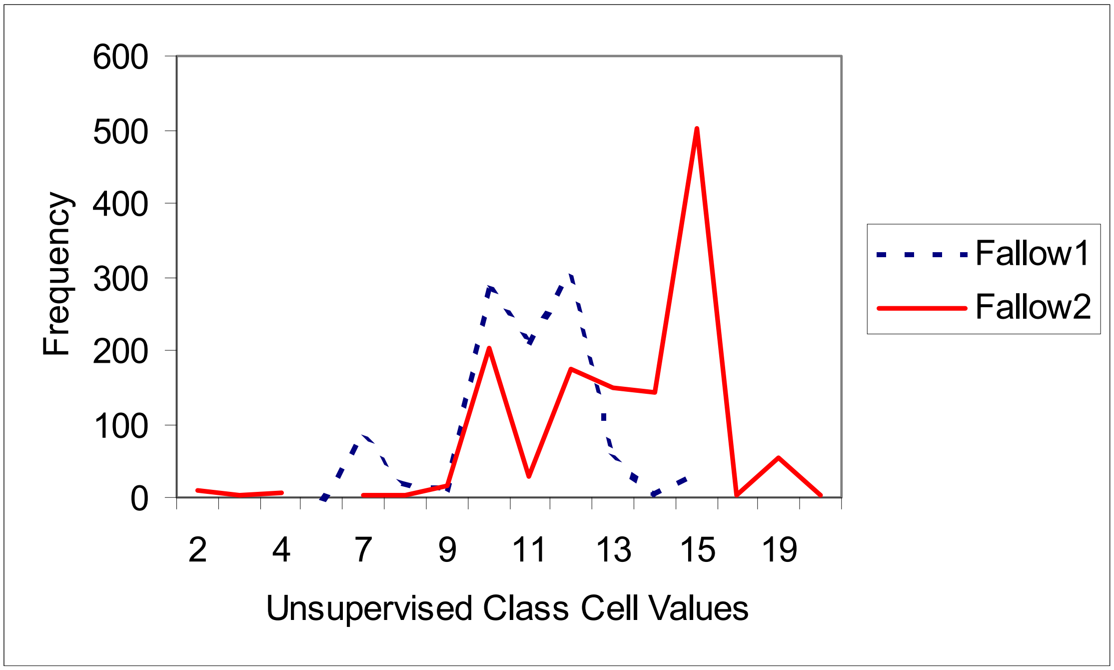
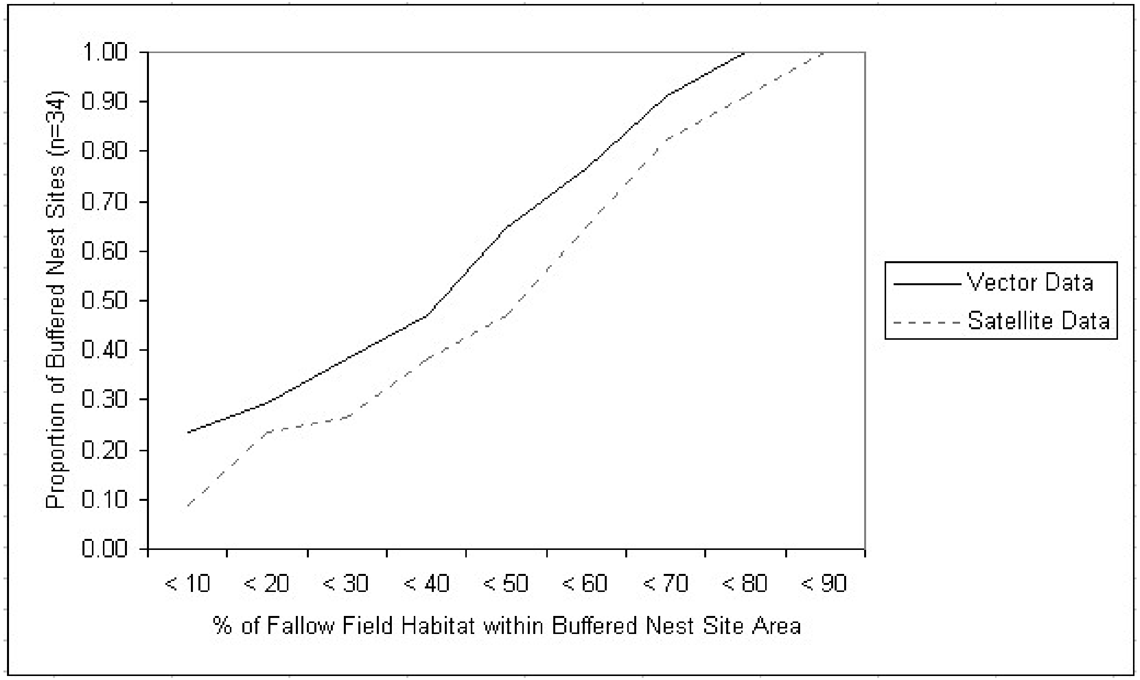
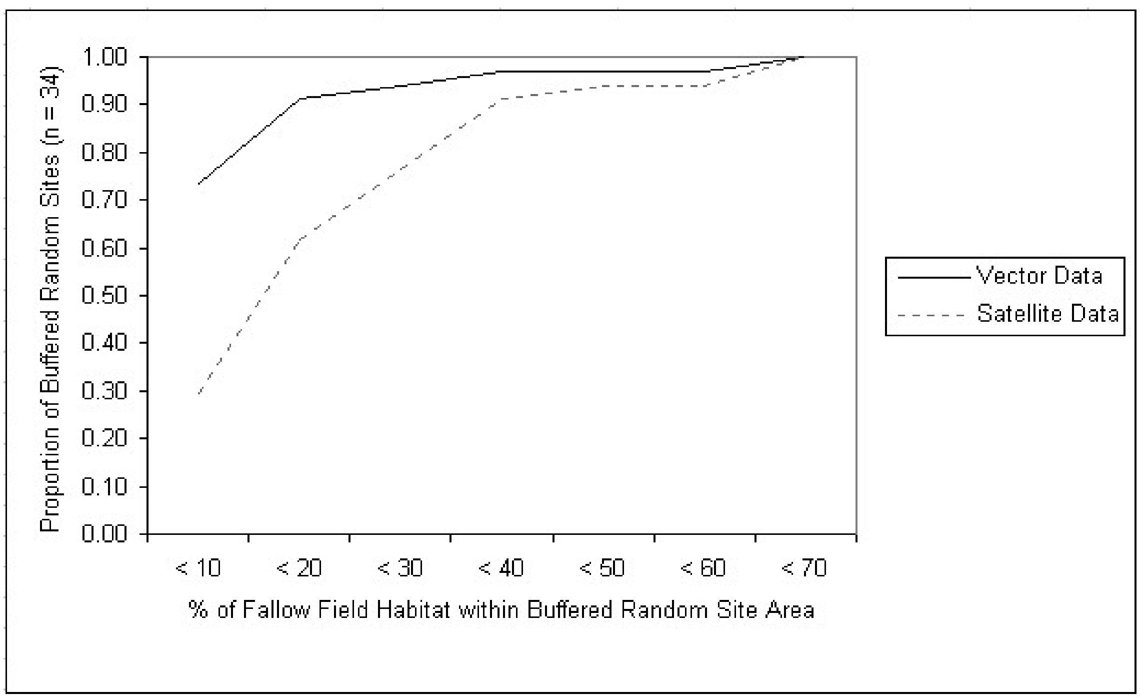

600
500
400
300
200
100
0
Frequency
2
4
7
9
11
13
15
19
Unsupervised Class Cell Values
Fallow1
Fallow2

Figure 5.8. For all random and nest buffers within the study area from 1998-1999, the percentage of fallow field$_{classified}$ was compared to the percentage fallow field$_{digitized}$.



1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion of Buffered Nest Sites (n=34)
< 10
< 20
< 30
< 40
< 50
< 60
< 70
< 80
< 90
% of Fallow Field Habitat within Buffered Nest Site Area
Vector Data
Satellite Data



1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion of Buffered Random Sites (n = 34)
< 10
< 20
< 30
< 40
< 50
< 60
< 70
% of Fallow Field Habitat within Buffered Random Site Area
Vector Data
Satellite Data

CHAPTER 6

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The benefits of the CRP have been many. One of the initial objectives was reduction in soil erosion, which has been accomplished (Farm Service Agency 1997). Other benefits have included connectivity between woodlots, enhanced seed dispersal capabilities among woodlots, maintenance of biodiversity, improvements in carbon flux, aesthetics, and improved wildlife habitat (Dunn et al. 1993, Farm Service Agency 1997). Conversion of marginal farm land into CRP conservation practices benefits landowners and managers in the following ways as well: improves long-term property value; reduces crop surplus and increases commodity prices; and financially rewards individual landowners and has acceptable long-run regional economic impacts (Redmond et al. 1990).

Economically, the CRP can provide a favorable return on investment. Lack of action is also resulting in lost revenue. Due to declining northern bobwhite (*Colinus virginianus*) and bobwhite hunter numbers it is estimated that $285 million was lost to rural Southeastern economy (Fies 1993; as cited by Lewis 1999). With little effort and enrollment in the CRP, a landowner may see a profit by leasing the land for quail hunting (Williams and Mjelde 1994).

Landowners in the Southeast, particularly Georgia, South Carolina, and Florida, chose to plant most of their CRP acreage into pine plantations. Many wildlife biologists feel this reforestation created more negatives than positives. Because the CRP is a voluntary set aside program funded with public money, some natural resource managers believe landowners should have some responsibility to wildlife and general environmental quality (Redmond et al. 1990, Allen et al. 1996). Changing demographics of non-industrial private forest (NIPF) landowners suggest that investment into wildlife, recreation, and aesthetics are increasingly acceptable management scenarios (Allen et al. 1996). The 1996 amendments to the Farm Bill placed equal emphasis on wildlife, soil conservation and control of commodity supply (Helinski 2000). The 1996 amendments also created the Environmental Benefits Index which ranks land offers based on environmental contributions. For those landowners wishing to re-enroll their CP3 pine plantings into the CRP, a thin or opening would be desirable, allowing them to score higher. Choices by NIPF landowners can influence the distribution and abundance of wildlife at the patch level and the immediate surrounding area. The cumulative effect of individual management decisions can influence wildlife within landscapes and regions (Allen et al. 1996). We evaluated avian relationships (i.e., nest sites, richness, abundance, and locations) to the landscape structure dominated by silvicultural and agricultural practices, including CRP pine plantations.

Songbirds.—Avian community management in CRP pine plantations requires both within patch and among patch diversity (i.e., diversity within the landscape). With >48,963 ha in Georgia and 42,053 ha in South Carolina alone, of CP11 CRP pine plantations, an enormous opportunity exists to use thinning and openings to create within patch diversity and subsequent diversity in the landscape. This study's findings suggest that recommendations to thin and create openings in CRP pine plantations would increase avian abundance of ground nesters. Management of the landscape around CRP pine plantations, including CRP pine plantations themselves, will affect the abundance of the avian community that uses the pine plantations. Patch density around pines were predictors of ground nesters, tree nesters, and Neotropical migrants. Ground nesters also responded positively to patch richness density and the amount of early successional habitat available in the surrounding habitat. Avian species respond to different cues within patches, at the patch level, and at the landscape level. Birds sensitive to patch size may respond to square, larger openings such as those created in the South Carolina study area. Understanding which wildlife species a manager wants to benefit, by modification to pine plantations, is crucial when implementing thins, creating openings, or modifying habitat surrounding CRP pine plantations. In general, modifications within CRP pine stands will result in higher avian (early successional) community richness, and modifications within CRP pine stands embedded in a diverse and patchy mosaic will result in increased abundance of early successional species. Due to the 1996 changes in the CRP, if landowners wish to profit by re-enrolling pine plantations into the program, thinning and openings should promote increased diversity of habitat and subsequently, bird species and abundance.

Northern bobwhite.—This study is not the first to discuss the improvements to northern bobwhite habitat that thinning pine plantations would bring, but it is the first to quantify the importance of open canopy planted pine in the landscape structure in the Southeast around nest sites at various scales. The CRP program has influenced the landscape in the Southeast by converting marginal cropland primarily into pine plantations. Northern bobwhite management in CRP pine plantations requires both within patch and patch diversity (i.e., diversity within the landscape). Based on this study's findings, recommendations to thin and create openings in CRP pine plantations should provide increased nesting opportunities for bobwhites. The benefit of open canopy planted pine for bobwhite will vary by patch and over time in a few short years.

A variety of management practices (e.g., burning, discing, herbicides, etc.) can be implemented to prolong or arrest the succession stage at the desired physical and vegetative structure desired for bobwhite management.

This study also quantitatively evaluated the relationship between landscape structure and nest site selection by bobwhites. Patch density and open canopy planted pine were consistent variables in the landscape around nest sites compared to random sites. Patch density could be increased in large monotypic stands of agricultural fields and closed canopy planted pine stands by interspersion of fallow field and thins, respectively. Evidence of several strong models in addition to the best model selected at the various scales indicate that landscapes can be structured in several ways and still be functionally equivalent (Guthery 1999) for bobwhite use. Economically, the decline in bobwhite numbers has resulted in a loss of revenue in the Southeast. Managers who desire to capitalize on the economic benefits of quail may need to be willing to subdivide large tracts of monotypic agricultural fields and silvicultural plantations into smaller fields interspersed with fallow or native grass and weed strips. A silvicultural management plant that promotes various age and successional stages of timber would be a plus.

Eastern wild turkey.—Spatial location and frequency of land cover types in the landscape greatly influences the amount of edge and type of land cover edge. Eastern wild turkey (*Meleagris gallopavo silvestris*) management in Georgia and elsewhere encourages an abundance of land cover edge. Turkey selection of land cover use based on distance to land cover types has been documented for some key life activities, such as nesting. Distance to land cover types to model turkey use has been incorporated in habitat evaluation procedures or other modeling efforts, but the associated edge type by land cover types has received little quantitative evaluation. This study's results not only supported previous findings of hardwood importance in landscapes but also showed affinity for or against specific edge combinations of land cover types. Understanding what edges are beneficial or are not beneficial to a species can be as important as creating or changing a land cover type in the first place.

The United States Department of Agriculture's recommendations for thinning and/ or opening pine stands for CRP re-enrollment could influence use by eastern wild turkey of these areas. This study's data suggest that use depends on season and sex, as well as vegetative component of the newly created opening or thinning. For example, a male turkey in the breeding season may avoid the portion a newly created opening if that opening's portion is bordering a hardwood, and the opening is allowed to act as a fallow field. However, evidence also indicates that openings in a pine stand could potentially create additional nesting habitat for turkey hens (Morgan 2000). Further, this study documented that a field-closed canopy planted pine edge could be favorable for breeding male turkeys, and open canopy planted pines would also serve post-incubating females that successfully hatched a nest. We agree with the recommendation to row thin and/or open 13 to 15-year old pine stands by $33% to maximize a diversity of use by male and female wild turkeys of pine plantations under the CRP, but caution that effort will be maximized only after careful consideration of where to place openings.

Hardwoods in our study area composed the greatest proportion (32%) of the defined landscape, and were used by turkeys proportionally more than what was available (Morgan 2000). Male and female turkeys were in or near hardwoods extensively throughout all seasons. We urge thoughtful management of the hardwood component in a landscape dominated by agricultural and silvicultural practices. The role of hardwoods in such a landscape is diverse, and their role as travel corridors may be essential for movement within a well diversified landscape, as well as among upland pine stands that lack proper forest structure. Further research into wild turkey selection of land cover types in a mixed agricultural and silvicultural landscape should continue to evaluate the importance of specific land cover edge types.

In general.—The avian community investigated in this study consisted primarily of early successional species, and species that benefit from edge. Landscape structure around the locations (i.e., nest and pine plantations) used by the wildlife species showed some consistent patterns. Northern bobwhite and the songbird community were positively benefited by an increase in patch density, which likely indicates more edge per area investigated. Further, more patches in the defined landscape scales we investigated could result in a smorgasbord of patches to choose from which contain the necessary benefits for the avian community (e.g., food, shelter, cover). Individual bird species will need some specific management regimes. Wildlife and land managers need to remember that not all species will be benefited by any 1 management action and some will be negatively affected. Our results indicate that thinning pine plantations will benefit most of the early successional species we investigated, by providing nesting sites and a diversity of within patch and across patch structure, as well as herbaceous vegetation, which may be used for food, shelter, and escape cover.

In addition, the far ranging eastern wild turkey that depends on older, mature, and diverse forests should not be adversely affected by conversion of marginal crop land into pine plantations if proper management of thins and opens result in an increase in food (e.g., food plots for wildlife), shelter, or cover. Morgan (2000) found fallow field sites, which thinned or opened pine plantations may mimic, were important in the landscape structure around nesting wild turkeys. Since not all patch configurations provide the same quality edge, landowners should contact knowledgeable wildlife professionals for assistance in planning size and locations of enrolled CRP acreage. Pine plantations enrolled in the CRP may, in landscapes heavily influenced by agricultural practices, provide some diversity and temporary early successional habitat on marginal cropland. Continued management of pine plantations could prolong the benefits to early successional species. Future research should focus on intensity and duration of thinning effects and use by particular species. Continued research into the relationship of landscape structure and species requirements is needed so spatial placement of CRP acreage can best optimize the desired effects. Our modeling efforts demonstrated that models created with a fine scale vector GIS database may be readily applied in other landscapes and regions by populating the data with a coarse scale raster GIS database. We provide a technique that can be used to accomplish this and encourage managers and researchers to test models and specific landscape metric conversions before implementation. Finally, we believe in the adage that if you are going to manage for some effect, manage it where it would do the most good.

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