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Effects of silvicultural techniques and landscape management on habitat quality and relative abundance for northern bobwhites in a pine plantation forest

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EFFECTS OF SILVICULTURAL TECHNIQUES AND LANDSCAPE MANAGEMENT ON HABITAT QUALITY AND RELATIVE ABUNDANCE FOR NORTHERN BOBWHITES IN A PINE PLANTATION FOREST

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ABSTRACT

Pine plantation forests are increasing in scope across the southeastern United States, particularly Louisiana. These areas provide poor quality bobwhite brood-rearing habitats, and become increasingly degraded without periodic disturbance. Poor quality habitat conditions at a landscape-level scale usually results in reduced fall bobwhite body weights, creating low survival rates.

We researched 4 understory vegetation management techniques (ie. mowing, no treatment, burn only, and imazapyr with burning) within pine plantations to evaluate their effects on vegetation composition and structure and on arthropod abundance and availability relative to bobwhite brooding habitat in 2002-2005. We used 1,155 human-imprinted bobwhite chicks to estimate foraging efficiency relative to the various treatments. We assumed that human-imprinted chicks foraged similarly to that of wild chicks, and that they provided a better indicator as to habitat quality in comparison to conventional entomological collection methods (ie. sweepnets and pitfalls).

Foraging efficiency of human-imprinted bobwhite chicks was greatest in imazapyr/ burn (RCW) treatments relative to the other treatments. RCW treatments produced vegetation characteristics similar to what could be considered fair brooding habitat relative to the other treatments. Important vegetation characteristics found in RCW treatments were different from the other treatments. Our results suggest that the RCW treatment is more effective at enhancing quality of brooding habitats in degraded pine plantation stands relative to the other treatments.

We also used bobwhite whistle counts collected from 2002-2005 to develop a GIS model that assessed landscape features associated with breeding males within a 200m

spatial scale. Landscape and class-level habitat variables associated with calling bobwhites were then extrapolated to predict occurrence based on specific habitat features.

Our landscape-level analysis determined that the probability of occurrence of bobwhites in an area was related positively to increasing patch diversity, but negatively to the homogeneity of patch types. At the class-level, bobwhite occurrence was positively influenced by increasing amounts of early successional habitat and edge complexity associated with two types of mature pine stands (unburned and RCW treatment). Negative bobwhite abundance was influenced by increasing amounts of 16-25 year old thinned pine plantations, and the amount of variation in patch size of unburned mature pine stands.

CHAPTER 1. INTRODUCTION, OBJECTIVES, AND GENERAL METHODS

INTRODUCTION

The northern bobwhite (*Colinus virginianus*; hereafter bobwhite) has endured a severe population decline in the United States since the early 1960's (Droege and Sauer 1990). Especially troubling is the fact that the most precipitous declines in bobwhite populations have occurred in the southern region of the United States, which is the center of its geographic range (Rosene 1969, Brennan 1991, Church et al. 1993). The Breeding Bird Survey (BBS) reports an average annual bobwhite decline of nearly 3% since 1960, and nearly 4% from 1982 to 1999 (Sauer et al. 2004). Projecting this trend into 2020 indicates an additional population loss of over 50% in the next two decades. BBS data also suggest that the bobwhite could be approaching extirpation in some states by the end of this decade (Dimmick et al. 2002).

In Louisiana, bobwhite populations have experienced an estimated 4.9% annual decline from 1982-2003 (Sauer et al. 2004). Bobwhite populations in Louisiana are primarily part of the West Gulf Coastal Plain region encompassing land in four southeastern states (Arkansas, Texas, Oklahoma, Louisiana), which in turn has suffered one of the most significant annual decline trends (-8.2%) of all the bird conservation regions in the United States (Dimmick et al. 2002). This devastating decline can be attributed primarily to the deterioration and loss of suitable early successional habitats associated with large-scale changes in agriculture and forestry (Roseberry and Klimstra 1984, Brennan 1991). Contributing to bobwhite declines are "clean-farming" practices, reduction of landscape heterogeneity from monoculture agriculture and forestry

production (Brennan 1991, Burger 2002), widespread herbicide/pesticide use, isolation of source populations, and an increase in predator abundance (Hurst et al. 1996).

Historically, southern pine forests of the lower Atlantic and Gulf coastal plain were dominated by longleaf pine (*Pinus palustris*) overstories with an herbaceous understory composition of forbs and grasses (Frost 1993). Forest systems were dominated by disturbance regimes (i.e., fire, wind), which formed these pine savannah-type ecosystems consisting of mature, old growth trees and early successional habitats. Most of these systems have now been converted to pine plantations, which contain pine species that grow faster than longleaf, have shorter stand rotations (20-30 years), are planted at higher densities, and lack disturbance regimes that retain early successional understory growth (Brennan 1991). As a result, wildlife species associated with this historical habitat type, such as the red-cockaded woodpecker (*Picoides borealis*; hereafter RCW) and gopher tortoise (*Gopherus polyphemus*), as well as ground nesting birds, such as Henslow's sparrow (*Ammodramus henslowii*), bobwhite, and Bachman's sparrow (*Aimophila aestivalis*) are all declining at a rapid rate (Sauer et al. 2004).

Bobwhite populations of the past were a byproduct of small-scale agriculture practices associated with the tenant farming system and the burning of woodlands to promote grasses for grazing livestock (Landers and Mueller 1989). Roseberry and Sudkamp (1998) suggested that bobwhites were primarily associated with diverse, patchy landscapes that contained moderate amounts of grassland, row crops, and abundant woody edge. Bobwhites require early successional habitats that consist of annual and perennial bunch grasses, shrubs, and herbaceous plants commonly associated with small

agriculture fields or edges and fire-managed forest ecosystems that have low basal areas (Rosene 1969, Roseberry and Klimstra 1984).

In forested ecosystems of the southern United States, the primary causes for bobwhite declines include widespread monoculture plantations, loblolly pine (*Pinus taeda*) in particular, which degrade rapidly with the suppression of fire (Stoddard 1931, Rosene 1969, Brennan 1991). Within these managed pine forest systems, if burning does occur, fire rotations usually exceed 5 years and are performed at large compartmental scales. Changes in the past 50 years to agriculture and large-scale forestry practices which maximize the production of crops, trees, or wood fiber generally reduce the quantity and quality of habitat for bobwhites (Fies et al. 1992).

In the south, intensively managed pine plantations that contain high basal areas and dense stocking rates associated with maximizing wood and fiber production throughout the stand rotation adversely affects bobwhite habitat suitability (Rosene 1969, Brennan 1991). Furthermore, early successional habitats such as clearcuts are short lived, and are useful to quail for only 1-5 years depending upon the site; hence, maintaining these early successional habitats with disturbance treatments such as thinning, fire, disking, selective herbicides, or mowing is crucial. Without the use of fire or other disturbance to maintain these required areas, habitat quality for bobwhites will decline rapidly through natural succession (Wilson et al. 1995, Burger 2002). In loblolly pine plantations, fire may not be used for up to 13 years post regeneration because of seedling tree mortality and dense stocking rates. Dense stands with closed canopies and little to no understory vegetation prevail during periods without frequent disturbance, which creates unsuitable conditions for bobwhites. The importance of disturbance

techniques such as site preparation, fire, and thinning to maintain these early successional habitat systems during the stand rotation is vital to the survival of the bobwhite. Engstrom et al. (1996) suggested that pine forest ecosystems will develop a thick hardwood midstory without disturbance, and eventually become a closed-canopied, mixed pine-hardwood forest with little herbaceous vegetation.

Forest management activities, such as thinning, burning, site-preparation, and reforestation, can be manipulated to enhance nesting, foraging, and brood-rearing habitats for bobwhites. Thinning mature pine stands to low basal areas (40-60 ft^2/acre) will create canopy gaps and allow sunlight to the forest floor to stimulate germination of grass and forb communities, as well as undesirable hardwoods in the absence of management such as fire. Prescribed burning on a short rotation (every 1-2 years) in conjunction with thinning is one of the most effective and cost-efficient management tools used to enhance the quality of bobwhite habitat (Stoddard 1931 and 1935, Landers and Mueller 1989, Brennan 1991). Habitat treatments such as fire usually result in an increase in number and vigor of legumes and other herbaceous plants, which are important to quail (Buckner and Landers 1979). Lay (1955) showed in Texas that herbaceous vegetation increased 200-300% the first two seasons post burn and grasses increased as much as 750% two seasons after burning. Cain et al. (1998) suggested that prescribed burning tended to increase percentage ground cover of grasses and forbs and decreased competing midstory woody regeneration.

Fire disturbance within pine forest ecosystems not only stimulates important grass and forb communities in the understory, but also promotes arthropod density and diversity (Hurst 1971). Habitat patches that contain a greater relative abundance of

arthropods than other patches are readily selected by bobwhites and provide increased foraging opportunities (Burger et al. 1993). In Mississippi, Hurst (1971) showed significant increases in important bobwhite food plants and greater biomasses of available insects for broods in burned areas than in unburned areas. Invertebrates are high in protein, comprise >80% of a bobwhite chicks' diet for their first two weeks of life (Nestler 1940), and also provide essential amino acids, water, and energy needed for rapid growth of skeletal, tissue, and muscular development (Hurst 1972, Jackson et al. 1987).

The RCW is listed as a federally endangered species (Federal Register, 13 October 1970, Volume 35 [199:16047], United States Forest Service, 1995) and has been the focus of pine forest management controversy in the southeastern United States for over 30 years. Intensive management of RCW colonies includes the maintenance of low basal area mature pine forests using short rotation (1-3 years) mowing and burning regimes in conjunction with herbicide treatments to reduce encroachment of woody species (Bowman et al. 1999). Both Fuller (1994) and Brennan (1991) stated that bobwhite management in the south was very similar and compatible with habitat management for RCW's, thus posing a distinct possibility for mutual management. At the Noxubee National Wildlife Refuge in Mississippi, managed mature pine stands that had RCW colonies contained more bobwhites than unmanaged old growth stands (Brennan 1991). Arthropod biomass and diversity also were greater in these managed RCW stands than in unmanaged stands of the same age (Hurst 1972, Fuller 1994).

The use of selective herbicides as a management tool in pine forest ecosystems is a relatively new practice that has emerged from the increasing social ridicule of

prescribed fire. Also, fire did not provide the desired effects due to its long absence from these habitats, providing leeway toward other effective management alternatives. Haines et al. (2001) stated that herbicide use had greatly increased over the years as an alternative management practice due to the restricted use of fire. Miller and Miller (2004) implied that herbicides improve conditions for timber production as well as wildlife habitat. Application of selective herbicides in southern pine forests can reduce competing hardwood mid-story vegetation and promote early successional plant communities favorable to bobwhites such as legumes (Fabaceae) and brambles (*Rubus* spp.); (Wigley et al. 2002). Selective herbicides that promote legumes, forbs, and grasses can enhance the composition, quality, and productivity of plant communities for bobwhite habitat (Guthery et al. 1987, Madison et al. 2001). In Louisiana, Jones and Chamberlain (2004) determined that imazapyr (Arsenal®; BASF Forestry Products, Research Triangle Park, N.C.) in conjunction with fire was crucial to maximize the effectiveness of herbicides for restoring habitat quality for bobwhites, where burning alone was incapable. Following spring and fall herbicide treatments, Washburn (2000) indicated that plant communities responded to herbicides by providing good brood-rearing habitat that had considerable canopy and forb coverage as well as plant species richness.

Recent research has evaluated effects of herbicide applications for enhancing brood-rearing and nesting habitats for bobwhites in a variety of habitats including pine forests (Madison et al.1995, Welch 2000, Greenfield et al. 2002, Jones and Chamberlain 2004). Formulation of effective management strategies for bobwhites in intensively managed pine forests requires more research because these systems continue to increase

across the southern United States (Fies et al. 1992, Trani et al. 2001). Wear and Greis (2002) forecasted that the area of pine plantation in the southern United States is projected to increase from nearly 12 million hectares in 1999 to over 22 million hectares by 2040. Research on pine forest silvicultural techniques involving herbicide use, prescribed fire, and management of RCW stands can be used to evaluate their effects on habitat alteration and composition as they relate to bobwhites. Research on population and landscape-level responses of bobwhites to techniques directly influencing habitat features and composition could provide some insight to biologists for landscape-level management strategies as they relate to Guthery's "usable space theory" (Guthery 1997). Guthery (1997) stated that the goal of habitat management for bobwhites should be to make all points on an area useable by bobwhites at all times, or increasing the amount of usable space, so as to provide for the maximum expression of their demographic potential.

OBJECTIVES

The two major goals for this research were: (1) to gather baseline data on the approximate abundance and distribution of male bobwhites during the breeding season (May - August), and (2) to examine the effects of selected understory vegetation management techniques on vegetation quality/structure, arthropod abundance/diversity, and arthropod availability to bobwhite chicks as they relate to brood-rearing habitat. Specifically, the objectives were:

1) Compare chick foraging efficiency in pine plantation habitats in response to treatments of prescribed fire in conjunction with imazapyr (Arsenal®), prescribed fire only, mowing, and no stand treatment.

2) Compare arthropod abundance and diversity in pine plantation habitats in response to treatments of prescribed fire in conjunction with imazapyr (Arsenal®), prescribed fire only, mowing, and no stand treatment.

3) Compare arthropod availability to bobwhite chicks in pine plantation habitats in response to treatments of prescribed fire in conjunction with imazapyr (Arsenal®), prescribed fire only, mowing, and no stand treatment.

4) Compare vegetation response in pine plantation habitats to treatments of prescribed fire in conjunction with imazapyr (Arsenal®), prescribed fire only, mowing, and no stand treatment.

5) Evaluate spring male distribution and abundance in relation to landscape composition and configuration in pine plantation habitats.

ORGANIZATION OF THESIS

Chapter 1 presents a general introduction to the decline of bobwhites and current management strategies to justify the purpose of this research project. Also included in Chapter 1 is a description of the study area, overall objectives of the research performed, and methodology used to apply stand treatments. Chapter 2 contains the first four objectives described above and management implications resulting from our research. Chapter 3 includes the last objective stated above in addition to some management implications based on our research.

GENERAL METHODS

Study Area

The Jackson-Bienville Wildlife Management Area (hereafter JBWMA) was the primary study site for this project. JBWMA is located 19 kilometers (12 miles)

southwest of the city of Ruston in Jackson, Bienville, and Lincoln parishes of north-central Louisiana (Figure 1.1). JBWMA is bordered on the east by U.S. Highway 167 and the west by LA Highway 147. The property encompasses approximately 13,137 hectares (32,460 acres) and is owned primarily by Weyerhaeuser Company and a few other small private landowners. It is composed of an extensive system of gravel roads and limited-use all terrain vehicle trails for public recreation, which are maintained by Weyerhaeuser Company.

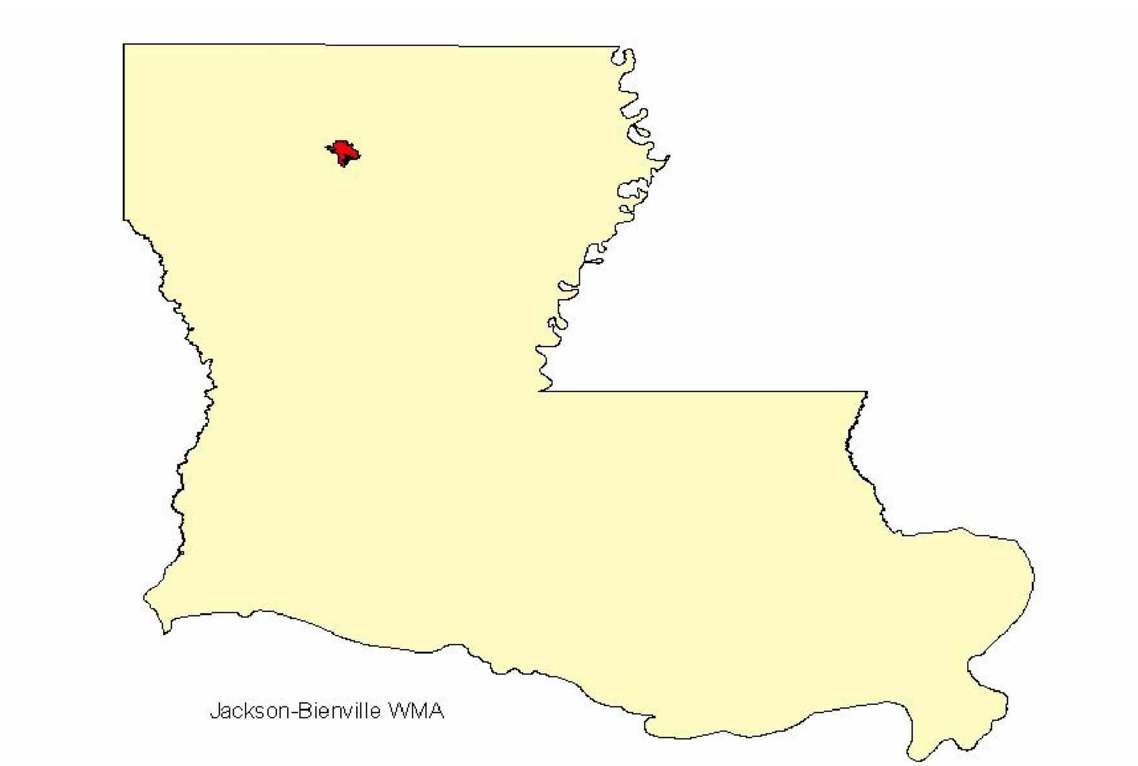

Figure 1.1. The 13,137 hectare Jackson-Bienville Wildlife Management Area located in north-central Louisiana.

JBWMA also is traversed by over 65 kilometers (40 miles) of gas pipelines and rights-of-way maintained by the Louisiana Department of Wildlife and Fisheries (hereafter LDWF) as linear food plots planted annually for wildlife. All properties within the management area are leased for no charge to LDWF and managed for public

recreation. Mean annual rainfall on JBWMA is 123.7 cm (48.7 inches), and mean annual temperature is 18.2º C (64.8º F).

Weyerhaeuser Company and other landowners primarily use the property for extensive wood fiber and timber production. This land use results in the property being composed primarily of even-aged, short rotation (25-30 years) loblolly pine plantations. Approximately 10-20% of JBWMA is considered to be bottomland hardwood forests containing Streamside Management Zones (SMZ's) and seasonally flooded low areas adjacent to rivers and streams. These areas are not harvested to protect water quality.

The topography of JBWMA exhibits gently rolling hills, consistent with an upland coastal plain site that borders the Dugdemona River and 5 other intermittent streams. Forested areas predominately consist of pine species such as loblolly and shortleaf (*Pinus echinata*). Other overstory and midstory associates are red maple (*Acer* rubrum), water oak (*Quercus nigra*), white oak (*Q. alba*), post oak (*Q. stellata*), southern red oak (*Q. falcata*), mockernut hickory (*Carya tomentosa*), pignut hickory (*C. glabra*), common persimmon (*Diospyros virginiana*), and sweetgum (*Liquidambar styraciflua*). Bottomland forested areas and SMZ's are predominately water oak, willow oak (*Q. phellos*), overcup oak (*Q. lyrata*), cow oak (*Q. michauxii*), blackgum (*Nyssa sylvatica*), sweetgum, red maple, American beech (*Fagus grandifolia*), and bald cypress (*Taxodium distichum*).

Dense understory species consist of a variety of shrubs, vines, and annual herbaceous plants, such as blackberry (*Rubus spp.*), greenbrier (*Smilax spp.*), poison ivy (*Toxicodendron radicans*), French mulberry (*Callicarpa americana*), red buckeye (*Aesculus pavia*), flowering dogwood (*Cornus florida*), yaupon (*Ilex vomitoria*), grape

(*Vitis spp.*), red maple, wax myrtle (*Morella cerifera*), eastern baccharis (*Baccharis halimifolia*), honeysuckle (*Lonicera spp.*), common sweetleaf (*Symplocos tinctoria*), sumacs (*Rhus spp.*), lespedezas (*Lespedeza spp.*), and beggarweeds (*Desmodium spp.*).

Until 2001, protected areas on JBWMA which contained active RCW colonies, had been historically managed by mowing pine stand understories. Major habitat improvements have occurred on the property from the recent management changes started in 2001, which included implemention of a prescribed burning schedule, imazapyr (Arsenal®) application, and thinning of stands. Although bobwhites and RCW colonies are the primary wildlife management concerns on JBWMA, other game species also are managed for such as whitetail deer (*Odocoileus virginianus*), wild turkeys (*Meleagris gallopavo*), eastern cottontails (*Sylvilagus floridanus*), raccoons (*Procyon lotor*), wild hogs (*Sus scrofa*), and gray squirrels (*Sciuris carolinensis*).

Herbicide and Mechanical Treatments

Various stands on JBWMA were selected for the herbicide, fire, and mechanical treatments to evaluate their effects on bobwhite habitat quality. Stands selected for these treatments contained mature pine trees (20+ years) and a prominent hardwood midstory component. Stands containing active RCW colonies or potential colonization sites also were selected for these treatments. Within these treatment stands, plots 1 to 2.5 hectares (3 to 5 acres) in size were evaluated for their effects on bobwhite brood habitat.

Herbicide (imazapyr; Arsenal®; BASF Forestry Products, Research Triangle Park, N.C.) mixtures were prepared immediately prior to application to minimize hydrolysis and degradation of the herbicide in the tanks (Miller and Glover 1991). Fall (September-October) imazapyr applications were implemented in selected stands from 2001 through

2005. Selected RCW colonies and adjacent stands were initially broadcast sprayed at an application rate of 1,120 g/ha (16 oz/acre) during September of 2001 and in new stands in the fall, each year thereafter. The LDWF and Weyerhaeuser Company applied the herbicide treatments with a skidder mounted with a T-boom implement. Following the initial herbicide treatment, a growing season (March-May) fire was implemented to remove residual dead or woody vegetation. Some stands that received fire were not treated with imazapyr prior to burning, and remained that way throughout the research period. All subsequent prescribed burning conducted at JBWMA occurred on a two year rotation in the same stands previously burned and in any new stands recently sprayed with imazapyr.

Other selected plots that were 1 to 2.5 hectares (3 to 5 acres) in size were treated mechanically by understory mowing in March and April of 2001, 2003, and 2005 prior to the breeding season, and contained no herbicide or burn treatments. These stands were mowed by LDWF every other year.

CHAPTER 2. EFFECTS OF UNDERSTORY VEGETATION MANAGEMENT TECHNIQUES ON ARTHROPODS AND VEGETATION STRUCTURE RELATIVE TO BOBWHITE BROOD HABITAT QUALITY

INTRODUCTION

The importance of arthropods in gamebird diets, especially young chicks, has been studied and documented throughout the world in many species such as the gray partridge (*Perdix perdix*; Potts 1986), red grouse (*Lagopus lagopus scoticus*; Hudson 1986), ring-necked pheasant (*Phasianus colchicus*; Hill 1985), eastern wild turkey (*Meleagris gallopavo silvestris*; Healy 1978), and bobwhites (Burger et al.1993).

Specific to bobwhites, the importance of arthropods has led researchers to index quality of brood foraging habitats using arthropod relative abundance measures to rank habitat patches (DeVos and Mueller 1993, Manley et al. 1994, Palmer et al. 2001). Indexing relative abundance of arthropods in a given habitat patch may involve the use of conventional invertebrate collection methods such as sweepnets (Panek 1997), vacuums (Sotherton et al. 1993), or pitfall traps (Shotzko and O'Keeffe 1986). However, these conventional methods may not accurately reflect the actual availability of arthropods to bobwhite chicks, therefore creating erroneous conclusions regarding quality of brood habitat (Smith and Burger 2005).

The use of human-imprinted bobwhite chicks as an index to determine quality of brood foraging habitats may provide a more accurate and biologically relevant technique than other conventional methods (Palmer et al. 2001, Smith and Burger 2005). Since imprinted bobwhite chicks are pen-strain, questions remain as to the legitimacy of using this method to simulate wild chick foraging efficiency and growth. Some assumptions made by Palmer et al. (2001) regarding the use of imprinted chicks were that they were

more likely to 1) sample arthropods in the same vegetation strata; 2) select highly nutritious arthropods; and 3) react with habitat edges and features, as would a wild bobwhite chick. Another question as to the relevance of the imprinted chick method is the assumption that diagnostic fragments of eaten arthropods are not passed out of the gizzard before chicks are euthanized, which could create underestimated datasets. Butler et al. (2004) suggested that human-imprinted chicks do not excrete arthropod-diagnostic fragments during foraging trials that are 30 minutes in duration. In Mississippi, Smith and Burger (2005) concluded that commercially-produced human imprinted chicks may serve as a reasonable biological assay for indexing arthropod availability and brood-habitat quality for wild northern bobwhite chicks.

We hypothesized that the use of imprinted chicks to estimate availability of arthropods to wild chicks would rank habitat patches differently than conventional methods (i.e., sweepnets, pitfall traps) used to estimate arthropod abundance and evaluate brood habitat quality. Our objective was to evaluate effects of mowing, burn only, imazapyr in conjunction with burning, and no treatment to understory vegetation within managed loblolly pine stands. Specifically, we evaluated the response of understory vegetation structure, vegetation composition, arthropod abundance, and arthropod availability to these treatments, and their relation to bobwhite brood habitat.

To test the use of imprinted chicks as a viable estimator of availability of arthropods to wild chicks relative to the understory vegetation treatments, we compared our arthropod abundance estimates from the conventional entomological methods (i.e., sweepnets, pitfall traps) to the imprinted chick crops (i.e., insect availability estimate) to evaluate bobwhite chick foraging efficiency. Microhabitat conditions also were

measured and compared among the stand treatments with emphasis placed on vegetation characteristics known to be important to bobwhite brood habitats (i.e., bareground, grass). Characteristics were compared among the stand treatments to evaluate their effects on brood habitat quality and structure.

METHODS

Stand Treatments

Loblolly stands greater than 20 years old were selected for the stand treatments and were the designated sites for chick foraging trials. Stands were selected based on the criteria that they had received no prior understory management and contained advanced hardwood understory succession. Treatments consisted of a variety of forest understory management techniques such as mowing, burn only, imazapyr in conjunction with burning, and no treatment. Stands that received mechanical treatments were bush-hogged in April-May of 2003 and 2005, and referred to as mowed stands (hereafter Mow). Stands that received growing season (April-May) prescribed fire were burned in 2003 and 2005, but were separated into two categories. Burned stands with a treatment history of fire only were referred to as burn only stands (hereafter Burn). Burned stands that received prior fall applications of imazapyr were referred to as RCW habitat improvement stands (hereafter RCW). The final stand treatment was the control (hereafter Control), and included stands that had received no understory treatments since 2000 and remained that way through the duration of the study. A total of 7 stands were used per treatment type, which were repeatedly sampled over the course of the sampling period (June-August; 2002-2005) until each batch of human-imprinted chicks were

exhausted. After the use of each batch of chicks (100-200 chicks at a time), a new batch was incubated and hatched, and the sampling process repeated.

Vegetation Structure Sampling

Microhabitat characteristics associated with vegetation structure and composition were recorded within each stand treatment immediately following chick foraging trials and sweepnet-pitfall sampling. Small areas, near 1 hectare in size (2-3 acres), within treatment stands were selected for sampling. All vegetation survey plots (1 per stand) were located at the approximate center of each sampling area. Vegetation composition characteristics recorded in each survey consisted of percentage cover of grasses, forbs, woody species, ferns, bare ground, and debris (Greenfield et al. 2002) within a 0.5-m^2 Daubenmire frame (Daubenmire 1959) at plot center and in each of the four cardinal directions 10 m from plot center. Canopy closure was measured from ground level using a spherical forest densiometer (Lemmon 1956) at plot center, and also in each of the 4 cardinal directions 10 m from plot center. Visual obstruction readings (VOR) were used as an index to understory vegetation structure, height, and density (Greenfield et al. 2002) at minimum, maximum, and average levels. VOR readings were determined with the use of a Robel pole (Robel et al. 1970) also from each of the 4 cardinal directions, 10 m from plot center. Each tree >10 cm in diameter at breast height (DBH) within the 10 m radius from plot center was counted to evaluate tree density within treatments.

Arthropod Abundance Sampling

Arthropod abundance was determined using a 38-cm diameter sweepnet and pitfall traps within the same treatment stands used for the chick foraging trials. Sweepnet samples were collected immediately following chick foraging trials along 3,

nonoverlapping 5-m transects (approximately 10-15 sweeps). Invertebrates sampled using sweepnets provide relative abundance estimates of arthropod populations within the stand (Schotzko and O'Keeffe 1989, Madison et al.1995). Sweepnet samples are not accurate assessments of all invertebrates available to foraging birds in an area, but do reflect the taxonomic heterogeneity and magnitude of the invertebrate biomass present in the vegetation (Evans et al. 1983). Arthropods collected using sweepnets were immediately frozen, stored in 120-ml sample cups containing ethyl alcohol, and later identified to taxonomic order. All arthropod orders that occurred infrequently were grouped together and included in the "other" category and consisted of the orders: Dermaptera, Dictyoptera, Ephemeroptera, Homoptera, Manatodea, Phasmatodea, and Thysanura.

Pitfall traps followed the design of Hooper-Bui and Pranschke (2006) to provide abundance estimates of invertebrates that could not be sampled using a sweepnet. Three pitfall traps were constructed along a diagonal transect through the middle of each treatment plot within each stand. Traps were set immediately following chick foraging trials. Each pitfall was constructed of one 400 ml plastic beaker, which held a smaller, trimmed-to-fit 250-ml beaker containing ethylene glycol (antifreeze solution). Traps were placed in the ground prior to running the chick foraging trials with the lip of the 400-ml beaker flush with the ground level. Three aluminum sheet metal strips (45 cm x 10 cm) were distributed evenly around the edge of the beaker, and served as array drift fences to funnel arthropods toward the sampling beaker. One 30 cm x 30 cm piece of aluminum sheet metal was folded over the sampling beaker to act as a rain guard during inclement weather conditions. Each pitfall trap was emptied in the evening, closed at night to avoid

nocturnal arthropods, and re-opened the following morning. Two trap days were sampled for each pitfall trap following foraging trials. Arthropods were removed from the ethylene glycol solution as soon as possible and transferred to 120-ml cups containing ethyl alcohol to avoid degradation of arthropod diagnostic features. Arthropods were then identified to taxonomic order.

All arthropods collected from chick crops, sweepnets, and pitfall traps were identified to taxonomic order using diagnostic body fragments including: heads, antennae, cerci, pronota, mandibles, femora, tarsi, tibiae, wings, and body segments (Moreby 1988). One arthropod was counted for all body parts identified. A total count of arthropods and mean dry weight of each order was then calculated for each respective sampling method.

Sweepnet and pitfall samples were used to determine relative abundance and diversity of arthropods, whereas foraging trials were used to determine availability of arthropods to chicks within each stand treatment. Chick crop estimates were then compared to abundance and diversity estimates (i.e., sweepnet, pitfall) to evaluate differences among stand treatment types relative to bobwhite brood habitat quality.

Bobwhite Chick Foraging Trials

Kimmel and Healy (1987) performed a technique for indexing arthropod abundance and availability using human-imprinted bobwhite chicks based upon observation counts of the number of insect captures per individual chick per unit time. This observation technique was not used in our study, considering the dense vegetation structure of loblolly pine forest understory and the possible bias of disturbing arthropods. The method we used followed the guidelines of Palmer et al. (2001), who estimated the

consumption rate of arthropods by imprinted chicks foraging in a variety of habitat patches. In our study, the stand treatments were considered habitat patches.

Within each of our stand treatments, the availability of arthropods to bobwhite chicks was estimated and compared using human-imprinted pen-strain bobwhite chicks following the guidelines of both Kimmel and Healy (1987) and Palmer et al. (2001). Pen-strain bobwhite eggs were obtained from a local commercial producer (Moon's Quail Farm; Homer, Louisiana) who collected eggs from birds held on site. A standard incubator (Model #1502, Georgia Quail Farms, Savannah, Georgia) was used to incubate 100-150 eggs per trial period at 37.5º C (99.5 ºF) for 21-24 days. Post-hatch chicks were transferred immediately to a brooder unit (Model #0701, Georgia Quail Farms, Savannah, Georgia), which contained heat lamps that maintained a constant temperature of 37.5º C (99.5 ºF).

Imprinting procedures began immediately following the hatch of the first chick by whistling to the chicks in the brooder unit and covering them with our hands. For imprinting to be successful, the handler must remain near the chicks (within 0.5 m) a minimum of 12 hours post hatch, whistle to them, and hand feed them arthropods (Palmer et al. 2001). Chicks were considered successfully imprinted when they readily responded to our whistle calls and followed the handler. Successfully imprinted chicks that were 2-11 days old were taken out twice daily for one hour training periods to expose them to a variety of habitats similar to the treatment stands and to familiarize them with arthropod foraging. Between these training periods, chicks were kept in brooders and fed a commercial diet of poultry starter feed.

Foraging trials were performed within the aforementioned stand treatments during the summer (June-August) of each year (2002-2005), which encaptured most of the brooding season for bobwhites in north-central Louisiana. The summer months were divided into 3 brood-rearing periods (June= early, July= middle, August= late) to evaluate temporal differences in chick foraging efficiency relative to the stand treatments. Trials were conducted with successfully imprinted chicks that were 10-14 days old to sample the availability of arthropods to chicks within each stand treatment. Arthropods were restricted from the chicks' diets for 18 hours prior to foraging trials and all food was restricted for 4 hours before the trials began to clear all crops and gizzards of arthropod parts and encourage foraging during trials. Two broods (5 chicks per brood) were released into the 1 hectare plots (2 to 3 acres) within each treatment stand for foraging trials between 0800 hours and 1400 hours on dry days only to standardize the sampling. Within each stand, one brood was placed near the center and the other near the edge of the plot. Handlers remained stationary and did not allow chicks to forage behind them to avoid disturbing arthropods on the foliage. Bobwhite chicks were allowed to forage for 30-minute periods, euthanized by either CO_2 asphyxiation or cervical dislocation, and immediately frozen for crop analysis in the lab. This research was conducted under the Louisiana State University Institutional Animal Care and Use Protocol AE 02-07. Crop contents were rinsed and emptied into 120-ml sample cups containing ethyl alcohol and identified to taxonomic order using a 30-X microscope. Borror and Delong's Introduction to the Study of Insects 7th edition was used to classify arthropods (Triplehorn and Johnson 2005).

Statistical Methods

To quantify vegetation responses relative to stand treatments, we performed an Analysis of Variance (ANOVA) using Proc MIXED (Bennington and Thayne 1994; Proc MIXED, SAS Institute Inc., Cary, North Carolina 2002) on microhabitat variables measured from each of the treatment stands. Pearson's correlation coefficients were first used to determine highly correlated microhabitat variables, which resulted in only 7 of the total 13 variables measured being retained. Retained variables included percentage bareground, forb, woody vegetation, grass, and vine, and minimum (VORmin) and average (VORavg) vertical obstruction heights. In the MIXED model, we were not interested in year or brood-rearing period effects, therefore we evaluated only treatment effects on vegetation responses. Year was included as a random effect and stand was nested within year and treatment. Results from the ANOVA procedure for the 7 retained vegetation variables presented comparisons between treatments for each individual variable (Type III Tests of Fixed Effects).

Similarly, to quantify both the overall arthropod abundance (all taxonomic orders) as well as individual taxonomic order abundance relative to stand treatments and brooding periods, we performed an ANOVA using the Proc MIXED procedure on sweepnet and pitfall trap data. One ANOVA was performed for the overall abundance estimate for all sweepnet and pitfall collections relative to stand treatment type and brood-rearing period. Individual ANOVA's were performed for each taxonomic order to quantify abundances of arthropods by order relative to stand treatment type and brood-rearing period. In the MIXED model for both analyses, year was included as a random effect and the plots where the samples were taken were nested within year, treatment, and

brooding period. The subplots (3 samples per plot) were nested within year, treatment, brooding period, and plot. The results from each ANOVA presented comparisons between treatments and brooding periods, and their effects on overall arthropod and individual taxonomic order abundance. Interactions between brooding period and treatment effects were not of interest for these analyses.

To quantify foraging efficiency of imprinted chicks relative to stand treatment and brood-rearing period, a logistic regression was designed using the Proc GLIMMIX procedure (Proc GLIMMIX, SAS Institute Inc., Cary, North Carolina 2002). The GLIMMIX procedure is a type of generalized linear mixed model (Blouin and Saxton 1990) that fits statistical models to data with correlations of nonconstant variability and where the response is not necessarily normally distributed. The GLIMMIX procedure was used to model the probability of a chick successfully catching an insect relative to stand treatment and brood-rearing period.

A binary ordered value of 0 (unsuccessful at catching insect) or 1 (successfully caught insect) was assigned to each chick. In the GLIMMIX model, year was used as a random effect and stand was nested within year, treatment, and brood-rearing period. Because brood (5 chicks per brood) was the experimental unit, it was nested within stand, year, treatment, and brood-rearing period. Results from the GLIMMIX procedure presented odds ratio estimates, Type III Tests of Fixed Effects, and Least Squares Means (Saxton's macro detransformed probabilities). Each of these results was used to interpret pairwise comparisons and interactions of treatment and brood-rearing period effects. All procedures were performed using SAS 9.1 and tested at $\alpha = 0.05$ significance level.

To determine arthropod species diversity among stand treatments, a Shannon-Weiner (S-W) diversity index was developed to account for the evenness and abundance of species (arthropods) within each treatment. The index was calculated by using the proportion of species, (i) relative to the total number of species (p_i) within each treatment, then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product was then summed across species and multiplied by -1. The S-W index values (H') can range from 0 to ~4.6 using the natural log (versus log10). A value near 0 would indicate that every individual in the sample is the same species. Conversely, a value near 4.6 would indicate that the number of individuals are evenly distributed among numerous species. The S-W index provides a measure of the likelihood that the next individual will be the same species as the previous sample (Krebs 1987).

RESULTS

Microhabitat Vegetation Characteristics

Percentage of woody vegetation ($F_{3,81}$= 9.66, P< 0.001), grass ($F_{3,81}$= 5.43, P= 0.002), forb ($F_{3,81}$= 5.47, P= 0.002), and bareground ($F_{3,81}$= 12.43, P< 0.001) differed among treatments. Percentage of woody vegetation was greatest in Control stands, whereas the percentage of forbs was 2X greater in RCW stands relative to the other treatments (Table 2.1). Mowed stands contained the greatest percentages of grass and debris relative to the other stand treatments, whereas Burn and RCW treatments both contained the greatest percentages of bareground. However, percentage of vine ($F_{3,81}$= 1.08, P= 0.361) was not different among treatments (Table 2.1).

VORmin ($F_{3,81}$= 3.47, P= 0.020) and VORavg ($F_{3,81}$= 4.97, P= 0.003) also differed among treatments. RCW and Mowed stands contained the lowest vegetation

heights and average heights relative to the Control and Burn stands. Tree DBH and distance to nearest tree from plot center also did not differ among treatments (Table 2.1).

Table 2.1. Mean (± SE) structural and compositional characteristics associated with 4 understory vegetation treatments on Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

	Treatments			
	Burn	**Control**	**RCW**	**Mow**
Variable	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Grass cover (%)	14.31 (0.99)	9.951 (1.17)	15.62 (1.09)	19.82 (1.29)
Forb cover (%)	11.78 (0.94)	9.551 (1.25)	21.12 (1.11)	12.85 (1.18)
Woody cover (%)	29.93 (1.73)	41.98 (2.71)	18.07 (1.43)	24.83 (1.61)
Vine cover (%)	8.041 (0.69)	5.981 (0.85)	8.271 (0.69)	6.711 (0.65)
Debris cover (%)	17.64 (1.19)	29.19 (2.09)	21.37 (1.36)	34.46 (1.33)
Bare ground cover (%)	11.55 (1.11)	1.441 (0.41)	11.19 (0.94)	0.921 (0.25)
Fern cover (%)	6.832 (1.51)	2.041 (0.72)	4.121 (0.92)	0.321 (0.14)
Canopy closure (%)	70.68 (1.62)	82.06 (1.63)	70.73 (1.26)	86.11 (0.88)
VORmin veg height (m)	0.471 (0.02)	0.610 (0.04)	0.281 (0.01)	0.270 (0.02)
VORmax veg. height (m)	0.961 (0.03)	1.131 (0.03)	0.710 (0.02)	0.651 (0.03)
VORavg veg height (m)	0.610 (0.02)	0.730 (0.04)	0.421 (0.02)	0.381 (0.02)
DBH (diameter breast height) (m)	0.340 (0.03)	0.311 (0.03)	0.322 (0.02)	0.312 (0.01)
Distance to nearest tree from plot center (m)	1.991 (0.21)	2.092 (0.20)	2.011 (0.17)	2.102 (0.13)

Arthropod Abundance

Differences in overall arthropod abundance were not detected among treatments ($F_{3,98}$= 2.48, P= 0.065) or brooding periods ($F_{2,98}$= 1.05, P= 0.352). However, several treatment and brooding period differences were detected for certain taxonomic orders. Orthoptera abundance differed by treatment ($F_{3,78}$= 3.73, P= 0.014) and brooding period ($F_{2,78}$= 4.52, P= 0.014), as did Araneae abundance, which differed by treatment ($F_{3,98}$=

2.62, P= 0.055) and brooding period ($F_{2,98}$= 3.88, P= 0.024). No treatment differences were detected for Hemiptera ($F_{3,66}$= 1.35, P= 0.266), Coleoptera ($F_{3,69}$= 0.54, P= 0.656), Diptera ($F_{3,35}$= 1.45, P= 0.246), Lepidoptera ($F_{3,26}$= 1.24, P= 0.314), Hymenoptera ($F_{3,99}$= 0.81, P= 0.494), or orders in the "other" category ($F_{3,74}$= 1.41, P= 0.246). No brooding period differences were detected for Hemiptera ($F_{2,66}$= 0.82, P= 0.311), Coleoptera ($F_{2,69}$= 0.98, P= 0.379), Diptera ($F_{2,35}$= 0.04, P= 0.957), Lepidoptera ($F_{2,26}$= 0.58, P= 0.569), Hymenoptera ($F_{2,99}$= 1.41, P= 0.245), or orders in the "other" category ($F_{2,74}$= 1.35, P= 0.265).

Shannon-Weiner diversity indices for all treatments reflected low arthropod heterogeneity for each sampling method (Table 2.2). Relative to the other stand treatments, the RCW treatment had the greatest arthropod diversity indices (H'= 1.252, 1.741, and 1.365) for pitfalls, sweepnets, and chick crops, respectively. The Control treatment produced the lowest arthropod diversity indices (H'= 1.047, 1.632, and 0.831) relative to the other treatments for pitfalls, sweepnets, and chick crops, respectively (Table 2.2).

Chick Foraging Efficiency

There were a total of 1,155 imprinted bobwhite chicks used to determine foraging efficiency relative to stand treatments and brood-rearing periods from 2002-2005. The number of chicks used in each treatment were as follows: Burn (n= 247), Control (n= 216), RCW (n= 405), Mow (n= 287). A total of 479 chicks were successful and 676 were unsuccessful at catching insects during foraging trials.

Table 2.2. Shannon-Weiner (S-W) diversity indices for arthropods collected in pitfall, sweepnet, and chick crop samples within 4 understory vegetation treatments at Jackson-Bienville Wildlife Management Area, Louisiana, June-August, 2002-2005.

		Treatments			
Method		**Burn**[a]	**Control**	**RCW**	**Mow**
Pitfalls					
	Total # of samples	72	66	126	81
	Total # of arthropods	718	847	1778	1449
	Diversity (H')[b] index	1.223	1.047	1.252	1.165
Sweepnets					
	Total # of samples	72	69	126	87
	Total # of arthropods	972	813	2121	1207
	Diversity (H') index	1.691	1.632	1.741	1.686
Chick crops					
	Total # of samples	247	216	405	287
	Total # of arthropods	179	204	444	237
	Diversity (H') index	0.968	0.831	1.365	1.135

[a] Burn treatments were not conducted prior to 2003, so indices and totals for this treatment are only for 2003-2005.
[b] The S-W Diversity index is calculated as: $H' = \sum [p_i*\ln(p_i)]$.

RCW treatment stands consistently produced greater chick foraging efficiency relative to the other treatments. However, chicks in our study did not consume as many arthropods (arthropods per chick = 0.183-2.023) as chicks used in other studies (arthropods per chick = 3-196; Welch 2000, Palmer et al. 2001; Table 2.3). Likewise, fewer arthropods were captured using sweepnets and pitfall traps in our study (arthropds per sample = 2.661-42.331) when compared to previous studies (arthropods per sample = 10.2-238.3; Hurst 1972, Jackson et al. 1987, Welch 2000, Palmer et al.2001; Table 2.3).

Table 2.3. Mean arthropods per sample with their associated standard errors (SE) from pitfall, sweepnet, and chick crop collections within 4 understory vegetation treatments on Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Year	Treatment[a]	Pitfall Samples Mean (SE)	Sweepnet Samples Mean (SE)	Chick Crops Mean (SE)
2002	B[b]	N/A	N/A	N/A
	C	20.55 (1.25)	2.66 (0.45)	0.19 (0.08)
	RCW[b]	15.27 (1.15)	2.72 (0.27)	0.18 (0.06)
	M	21.72 (1.60)	5.05 (1.03)	0.25 (0.08)
2003	B	9.60 (0.67)	3.33 (0.28)	0.74 (0.24)
	C	14.08 (2.61)	4.33 (0.88)	2.02 (0.64)
	RCW	17.37 (1.68)	3.33 (0.20)	1.22 (0.19)
	M	42.33 (6.80)	3.61 (0.27)	1.34 (0.38)
2004	B	13.91 (0.89)	21.85 (0.76)	0.74 (0.11)
	C	10.83 (0.89)	18.92 (0.71)	1.05 (0.17)
	RCW	14.83 (1.02)	31.07 (0.79)	1.28 (0.07)
	M	9.41 (0.89)	16.71 (0.53)	1.15 (0.11)
2005	B	7.83 (0.77)	12.86 (0.52)	0.71 (0.10)
	C	4.00 (0.42)	21.58 (1.21)	0.76 (0.13)
	RCW	10.50 (1.17)	17.35 (0.51)	1.24 (0.08)
	M	8.20 (0.59)	22.03 (0.88)	0.65 (0.14)

[a] Treatments: B= burn only, C= control (no treatment), RCW= imazapyr treatment followed by a spring burn, M= mow only.
[b]Burn treatments were conducted in 2003 and 2005; i.e. 2002 RCW treatment is imazapyr-only without the growing season burn.

Treatment and brood-rearing period did not interact ($F_{6,94}$= 1.42, P= 0.215) to affect foraging efficiency of chicks. However, foraging efficiency did differ among treatments ($F_{3,94}$= 9.98, P= <0.001) and brood-rearing periods ($F_{2,94}$= 4.84, P= 0.010). Saxton's macro produced detransformed probabilities which showed that foraging efficiency was greatest in RCW treated stands relative to the other treatment stands (Figure 2.1).

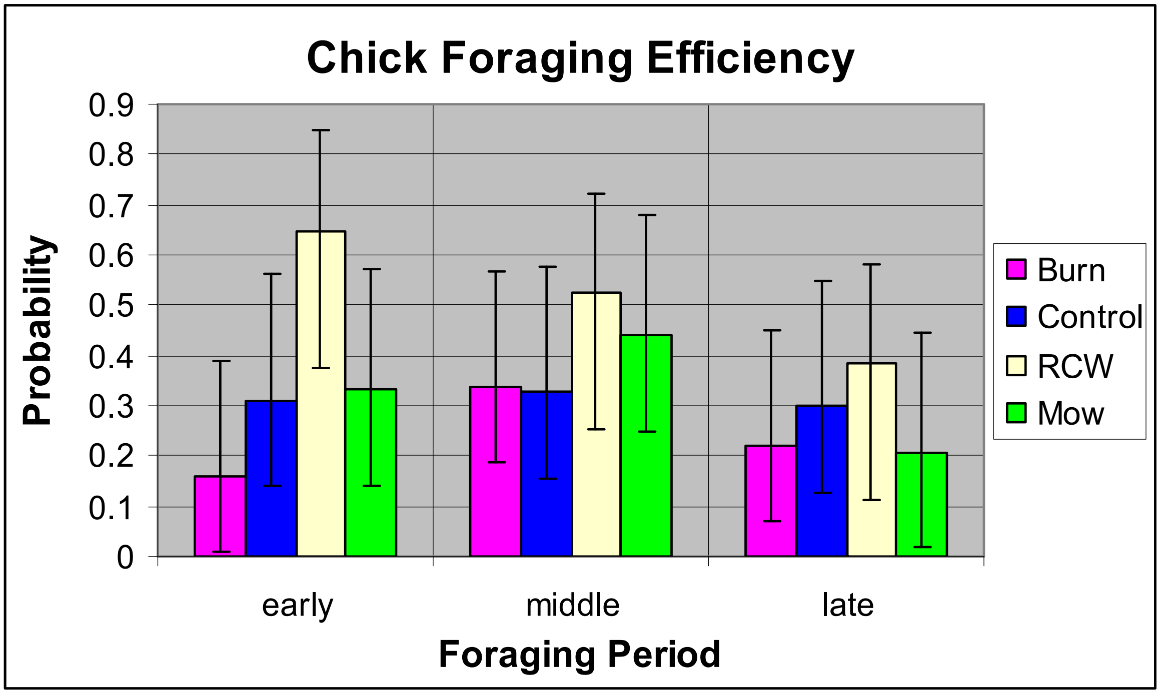

Figure 2.1. Imprinted chick foraging probabilities, with their associated confidence intervals, for 4 understory vegetation management treatments in early (June), middle (July), and late (August) chick foraging periods of the brooding season at Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Odds ratio comparisons of treatments revealed that foraging efficiency in RCW stands was consistently greater than the other treatments. For example, foraging efficiency in RCW stands was 137% greater than in Control stands (Table 2.4). Relative to season, foraging efficiency was greatest during the middle (July) brood-rearing period when compared to the early (June) and late (August) periods. However, foraging efficiency did not differ between early and late brood-rearing periods. For example, chick foraging efficiency during the middle brood-rearing period was 82% greater than during the late period (Table 2.5).

Table 2.4. Pairwise comparisons of treatments, with their associated confidence intervals, using odds ratios to evaluate chick foraging efficiency among 4 understory vegetation management treatments at Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Treatment Comparison	Estimate	95% Confidence		Difference
Mow vs. RCW	0.435	0.281	0.675	-57%
Mow vs. Control	1.032	0.637	1.673	+3%
Mow vs. Burn	1.552	0.943	2.555	+55%
RCW vs. Control	2.372	1.470	3.828	+137%
RCW vs. Burn	3.567	2.163	5.884	+256%
Control vs. Burn	1.504	0.876	2.582	+50%

Table 2.5. Pairwise comparisons, with their associated confidence intervals, using odds ratios of chick foraging efficiency among 3 periods of the brood-rearing season at Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Period Comparison	Estimate	95% Confidence		Difference
Middle vs. Late	1.821	1.242	2.670	+82%
Middle vs. Early	1.289	0.826	2.012	+29%
Late vs. Early	0.708	0.444	1.129	-30%

DISCUSSION

Pine plantations, given their current management regime, are generally considered to provide poor quality bobwhite brooding habitat (Brennan 1991). These homogenous landscapes are continuing to increase in their extent across the southeastern United States, particularly north Louisiana, and could be a partial explanation toward the factors influencing bobwhite declines in that region. Guthery (1997) stated that the goal for bobwhite habitat management should be to make all points on an area useable by bobwhites at all times, so as to increase their useable space to provide for the maximum expression of their demographic potential. Relative to this “useable space” theory, we

evaluated some current mid-rotational understory vegetation treatments to investigate possibilities for improving these habitats; hence alteration of understory vegetation composition/structure to enhance quality of brood-rearing habitats. Quality brood-rearing habitat is a limiting factor affecting survival rates of bobwhite broods within these pine systems (M. J. Chamberlain, unpublished data), and is a function of vegetation composition and structure, which in turn affects invertebrate abundance and availability. Past research has determined that the quality of bobwhite brood-rearing habitat is directly dependent upon invertebrate abundance and availability (Palmer et al. 2001), vegetation composition and structure (Madison et al. 1995), and can be a major factor determining chick survival (Hurst 1972).

Specifically, the objective of our study was to evaluate various understory treatments for their effects on bobwhite brood habitat conditions (i.e. arthropod availability/abundance and vegetation composition/structure). Fall imazapyr application followed by growing season fire (RCW treatment) was generally more effective than fire alone, mowing, or no treatment at improving chick foraging efficiency, arthropod diversity, and vegetation structure/composition. Only one treatment, RCW, produced vegetation characteristics similar to what could be considered reasonable brood habitat conditions. Hurst (1972) and Burger et al. (1990) both reported optimal brood habitat conditions to be areas that contained great plant species richness, a considerable amount of forbs, and sufficient bareground to allow bobwhite chicks to forage freely and find invertebrates. Relative to the other treatments, the RCW treatment consistently produced greater forb and grass abundances in the understory, which in turn attracted more invertebates to create better foraging opportunities for bobwhite chicks. Healy (1978)

found higher invertebrate populations in forest stands with abundant herbaceous vegetation. In east-central Mississippi, the number of forbs, vines, and leguminous plants increased one year post-imazapyr application in treated loblolly stands (Watkins et al. 1989). Percentage bareground has been reported optimal at 25-75% for nesting and brood-rearing habitats (Rice et al. 1993, Taylor and Burger 2000). In our study, RCW treatment stands only contained a mean of 11.19% bareground from 2002-2005. This is possibly attributed to the build up of debris and thatch that one year of burning could not remove. Relative to the treatments that did not receive fire at any point during the duration of the study (i.e. Control and Mow), bareground was significantly different from treatments that did receive fire.

RCW treatments improved understory vegetation characteristics as they relate to bobwhites. Similarly, these understory management techniques are used for enhancing habitats for Red cockaded woodpeckers, an endangered species (Welch 2000), which illustrates the distinct possibility for mutual management. Intensive management of RCW colonies includes the maintenance of low basal area mature pine forests using short rotation (1-3 years) mowing and burning regimes in conjunction with herbicide treatments to reduce encroachment of woody species (Bowman et al. 1999). The RCW treatment effects in our study illustrate the importance of using herbicides in conjunction with burning to reclaim early successional habitats in pine stands where burning or mowing alone could not accomplish this task. In Louisiana, Jones and Chamberlain (2004) concluded that imazapyr in conjunction with fire was more effective than prescribed fire alone at improving vegetational structure and composition for brood-rearing bobwhites.

In our study, stands that received understory mowing treatments contained the greatest percentage of grass and debris and the lowest percentage of bareground. The low percentage of bareground was a direct result of thatch and debris build up from repeated mowing treatments. High percentages in grass could be attributed to the timing of the mowing treatments, which was occurred approximately 3-4 weeks prior to sampling. Late mowing treatments did not allow woody plant sprouts enough time to regenerate. Welch et al. (2004) determined that mechanically treated pine stands unfortunately serve only to promote an increase in the abundance of woody stem regeneration and debris build up, ultimately reducing the amount and diversity of grasses and forbs within the understory.

Fire treatments that reduce hardwood stem densities can take repeated years of burning alone to restore early successional plant communities (Cain et al. 1998). Our study showed similar results with stands receiving only a burn treatment containing significant bareground, but retaining high percentages of woody vegetation. The high percentage of woody stems was attributable to not using imazapyr prior to burning, and the high percentage of bareground was most likely a result of residual woody plants shading out the understory germination of new forbs and grasses after the litter layer was removed. Welch et al. (2004) pointed out that a single application of imazapyr can control hardwood encroachment and stimulate herbaceous species growth. Likewise in Mississippi, a study combining the use of imazapyr and fire treatments in thinned loblolly stands increased species richness and coverage of grasses, forbs, and native legumes (Thompson et al. 2002).

Without the use of fire or other disturbance to maintain early successional habitats, habitat quality for bobwhites will decline rapidly through natural succession (Wilson et al. 1995, Burger 2002). Relative to bobwhite brood-rearing habitat, natural succession quickly degraded the quality of vegetation composition and structure found within our Control stands that received no disturbance treatment. These stands contained the greatest percentages of woody vegetation and the lowest forb, bareground, and grass percentages. Engstrom et al. (1996) determined that pine forest ecosystems will develop a thick hardwood midstory without disturbance, and eventually become a closed canopied mixed pine-hardwood forest with little herbaceous vegetation.

High tree densities (basal areas >24 m^2/ha) within pine stands in our study affected the germination of early successional communities post-treatment. Shading from canopy closure reduced the efficacy of fire or other treatments to allow early successional grasses and forbs to respond. Thinning maintenance of mature pine stands to low basal areas (12-18 m^2/ha) will create canopy gaps and allow sunlight to the forest floor to stimulate germination of grass and forb communities (Bowman et al. 1999). In our study, the mean percentage canopy closure at ground level for stands treated with fire (Burn and RCW) was near 70%, but for stands without fire as a treatment, was >82% (Mow and Control). Wilson et al. (1995) pointed out that bobwhites occurred most frequently in stands which had a wildlife stand improvement (thinning) and a fire treatment that produced stand canopy closure percentages that were <67%.

The manipulation of vegetation composition and structure can directly influence the diversity, abundance, and availability of invertebrates to young bobwhite chicks (Southwood et al.1979). Bobwhite chicks require these invertebrates, which are high in

protein, comprise >80% of their diet for their first two weeks of life (Nestler 1940), and also provide essential amino acids, water, and energy needed for survival and growth (Hurst 1972, Jackson et al. 1987). During foraging periods, wild chicks are subjected to a variety of factors relating to optimal foraging theories (Charnov 1976, Krebs et al. 1983), which could determine their survival. Factors influencing these optimal feeding conditions can include but are not limited to inclement weather conditions, habitat composition and structure, invertebrate abundance/availability, predation, and disease (Stoddard 1931, Rosene 1969, Burger et al. 1993). Relative to our study, degraded habitats such as those found in pine plantations create decreases in the accessibility and availability of invertebrates to bobwhite chicks, therefore promoting an increase in foraging time. Prolonged foraging periods expose chicks to more survival factors and could result in greater brood mortality.

Both Palmer et al. (2001) and Smith and Burger (2005) determined that the use of human-imprinted pen strain bobwhite chicks were a reasonable biological assay for more accurate indices regarding habitat foraging quality and arthropod availability as they pertain to wild bobwhite chicks. We inherited Palmer et al.'s (2001) explicit assumptions that chick foraging behaviors were innate and that they provided valuable information as to the availability and selection of arthropods by wild chicks. In our study, chick foraging efficiency and arthropod abundance within the treatment stands was directly influenced by the structure and composition of the understory vegetation. As a result of the treatments, RCW stands produced more insects and created an increased chick foraging efficiency relative to the other treatments. Hurst (1972) reported that insect abundance increases in areas after treatment with prescribed fire. However, fire

treatments which reduce hardwood stem densities can take repeated years of burning alone to restore early successional plant communities (Cain et al. 1998). In Florida, DeVos and Mueller (1993) reported bobwhite broods using areas located in upland pine woodlands that had been burned the previous 2 years. Welch et al. (2004) showed that following imazapyr treatment, vegetative communities can be maintained for prolonged periods by using traditional methods such as fire.

Our arthropod abundance measurements suggest that conventional methods (i.e. sweepnet and pitfall) were not accurate assessments of the invertebrates actually available to foraging chicks, but do reflect the magnitude of invertebrate diversity and biomass present in the vegetation. Only 41% (479 / 1,155 total) of the chicks in our study were successful at consuming arthropods during foraging trials. Chicks in our study did not consume as many arthropods as chicks used in other studies (Welch 2000, Palmer et al. 2001), and likewise fewer arthropods were captured using sweepnets and pitfall traps in our study when compared to previous studies (Hurst 1972, Jackson et al. 1987, Welch 2000, Palmer et al.2001). Poor brooding habitat may result in chicks gaining less weight for fall, negatively impacting their winter survival. Also, adult weights of bobwhites on the JBWMA are 10-20% lower than for bobwhites at similar latitudes in other parts of their range (M. J. Chamberlain, unpublished data). Adult hen turkeys with reduced fall weights were less likely to survive to breed and less likely to nest when entering the fall season in poor shape (Porter et al. 1983). Low abundances and availability of arthropods, as well as reduced adult body weights, indicate that habitat quality found within the pine plantation stands on JBWMA is likely degraded.

The effects of vegetation management practices within pine plantation stands can alter understory plant composition and structure, create a greater diversity, abundance, and availability of invertebrates to bobwhite chicks, and enhance brood survival. Bobwhite brood survival is a function of chicks having access to quality foraging habitats; hence poor quality brood habitat at a landscape-level scale (i.e. extensive landscapes of pine plantation forests) will result in lower recruitment and survival rates across their geographic range. The Northern Bobwhite Conservation Initiative (NBCI) is directed at this problem and promotes the altering of silvicultural methods on approximately 50 million acres of forest lands, primarily southern pine forests, to encourage favorable grass and forb communities (Dimmick et al. 2002). Selective herbicides provide a socially acceptable alternative or supplement for the use of prescribed fire when needed to alter the composition and productivity of desired plant communities for bobwhites (Washburn et al. 2000). Selective use of herbicides such as imazapyr, with or without fire, could play an important role in this extensive timber land improvement proposed by the NBCI relative to bobwhite brood habitat in the future.

Management Implications

Traditionally, land managers in southern pine forests have used mechanical treatments (i.e., mowing, thinning, roller chopping) and fire to manage pine stands for bobwhites with the ultimate goal of reducing woody vegetation and increasing herbaceous ground cover. Unfortunately, mechanical treatments serve to only increase the prevalence of hardwood sprouts and ground litter. When fire is used, it is usually implemented with long rotation periods (>5 years), which typically produce only short-term benefits. Fire can be a useful tool for managing bobwhites in that it removes forest

litter, making it easier to locate foods; it promotes scarification and germination of important food plants; and it promotes production of newly sprouted vegetation that attracts abundant insect populations. However, when fire is not used on a consistent basis (every 2-3 years), unwanted hardwoods will regenerate, degrading the quality of the habitat rapidly in relation to bobwhites. Chen et al. (1977) found that repeated burn treatments in southern Alabama pine forests were effective in maintaining succulent browse and stimulating the growth of herb species. Fire used on a consistent 2-3 year rotation during the growing season (March-April) can be very effective at controlling hardwood regeneration and promoting early successional plant communities.

Goodrum (1960) suggested that habitat quality for northern bobwhites can be enhanced with the use of herbicide treatments. Selective herbicides such as imazapyr (Arsenal®) can kill or severely suppress both aboveground and belowground portions of hardwood species (Welch et al. 2004), and when used in conjunction with fire, maximizes its effectiveness for enhancing bobwhite habitat (Jones and Chamberlain 2004). Imazapyr, one of the most commonly used silvicultural herbicides in the southern United States (Shepard et al. 2004), can be used to jumpstart burning programs by reducing the time needed to remove the woody component from stand understories and promote herbaceous vegetation growth before prescribed fire is applied. Both Welch et al. (2004) and Jones and Chamberlain (2004) recommended a one-time treatment of imazapyr to restore or improve habitat quality for bobwhites in pine forests where hardwood encroachment is severe. Previous research has shown that herbicides generally reduce plant species diversity the first growing season after treatment, but plant

communities usually recover to become more diverse in subsequent years (Miller and Miller 2004).

The active herbicide and prescribed fire program started on JBWMA in 2002 was primarily implemented for RCW and quail habitat improvement. The goal of this program was to reduce stand hardwood midstories, promote early successional understories, and improve habitat quality for RCW's and bobwhite quail. While there were many beneficial improvements derived from the active burning and imazapyr treatments on JBWMA, this management needs to be continued and expanded in subsequent years to maintain the current habitat quality of these stands and to create additional habitats suitable for nesting and brood-rearing bobwhites.

CHAPTER 3. EFFECTS OF LANDSCAPE COMPOSITION AND CONFIGURATION ON NORTHERN BOBWHITE DISTRIBUTION AND ABUNDANCE IN A PINE PLANTATION FOREST

INTRODUCTION

Precipitous declines in bobwhite populations, particularly in the southern United States, continue to discourage land managers. These declines can be attributed primarily to a combination of factors, including the deterioration and loss of suitable early successional habitats associated with large-scale changes in agriculture and forestry (Roseberry and Klimstra 1984, Brennan 1991). Burger (2002) stated that large-scale, intensive monoculture production in agriculture and forestry practices have lost many early successional communities and reduced landscape heterogeneity. These exacerbating land-use patterns and trends have motivated the need for effective management planning and interpretation of habitat characteristics associated with bobwhites at various spatial scales.

Traditional bobwhite habitat evaluation and management focused on discrete local site conditions without regard to their spatial, landscape-level aspects or orientation in physical space (Roseberry 1993). Today, advanced technology using Geographic Information Systems (GIS) can be used to examine both finite and broad-scale landscape associations of wildlife and their habitats. A few recent uses of this concept were published in manuscripts pertaining to neotropical migratory songbirds (Keller and Anderson 1992), spotted owls (*Strix occidentalis*; Hunter et al. 1995), northern bobwhites; (Roseberry and Sudkamp 1998, Schairer et al. 1999), and raccoons (*Procyon lotor*; Henner et al. 2004). Goals of these studies focused on the spatial relationships of various wildlife species to different components of habitat configuration and

management. Turner et al. (2001) pointed out that the fundamental process of landscape ecology and evaluation is the emphasis of the interactions between spatial patterns and ecological processes.

Within pine forests of the south, of which bobwhites are associated, land use changes and conversions are occurring at a tremendous rate. Many areas across the southern United States that were once farmed for crops have been converted to large scale monocultures of agriculture and pine plantations (Brennan 1991). Short rotation (20-30 years) monoculture plantations, primarily consisting of loblolly pine, contain dense stocking rates and high basal areas which are maintained throughout the rotation so that wood and fiber production are maximized. This practice serves only to minimize quail production in these systems (Rosene 1969). Without the use of fire or other disturbance to maintain plantations throughout the stand rotation, the quality of the habitat for bobwhites will decline rapidly through natural succession (Wilson et al. 1995, Burger 2002).

In pine-dominated ecosystems, early successional plant communities required by bobwhites are short lived (2-4 years) and usually a result of natural disturbance (wind or fire), site preparation, occasional thinning, or timber harvest (Roseberry and Klimstra 1984). These ephemeral plant communities are important to bobwhites and can only be sustained throughout the rotation by inducing man-made disturbance regimes (Brennan 1991). Other important factors that greatly influence bobwhite production at the landscape-level scale include the composition, configuration, and juxtaposition of these plant communities within the landscape (Roseberry and Sudkamp 1998).

Quail biologists need to incorporate certain concepts of landscape ecology, exploit emerging technologies such as GIS (Geographic Information Systems) and habitat modeling, and consider the significance of geographic scale to formulate future management decisions (Roseberry 1993). There is insufficient knowledge regarding the relationships between bobwhite population dynamics and landscape ecology, but with the use of improving technologies, managers can both spatially identify areas of interest for bobwhite management and evaluate habitat management programs over large regions (Schairer et al. 1999). To assess relationships between bobwhite abundance and landscape composition and configuration within pine plantation forests, we examined relationships between the abundance of breeding males to landscape characteristics found on Jackson Bienville Wildlife Management Area in north central Louisiana from 2002-2005.

METHODS

Breeding Male Surveys

Call count stations and routes were established on JBWMA during 2002 to monitor abundance and distribution of northern bobwhites in pine plantation forests. Stations were established every 0.8 km (0.5 mile) along the road system of JBWMA (total of 60 stations). Universal Transverse Mercator (UTM) coordinates were recorded from each station location to ensure that the same station was used in each of the 4 consecutive monitoring years (2002-2005). The spacing system of 0.8 km (0.5 mile) between stations prevented counting the same calling bird at consecutive stations. These stations were monitored twice weekly, for 5 minute intervals during the breeding season (May-July) each year (2002-2005), beginning 30 minutes before sunrise until the route

was completed, which generally required 2-3 hours. The frequency of male bobwhite vocalizations were recorded along with an azimuthal direction from each station. DeMaso et al. (1992) stated that vocalization frequency has been used as a density index for northern bobwhites, and that whistling male counts in summer can be used to predict crude estimates of autumn relative abundance.

GIS Analysis

A digital landcover geodatabase was developed in ArcView 3.3 (Environmental Systems Research Inc. (ESRI), Redlands, California, USA) using archived 7.5 minute Digital Orthophoto Quarter Quadrangles (DOQQ's) obtained from the Weyerhaeuser Company. We developed spatial landcover layers for each of the 4 years (2002-2005), which were digitized using ArcView 3.3. Within each of the 4 landcover layers, stand polygons were digitized and based on 7 habitat types. Habitat types of each stand on JBWMA were determined from a GIS database provided by the Weyerhaeuser Company that contained landcover types, stand ages, and management history. Each digitized stand or polygon contained its own individual attributes, which were classified using habitat types to encapsulate landcover changes that occurred between the years 2002-2005.

Habitat type classification for each of the 4 landcovers are as follows (Appendix):

1.) **Early successional stands**- 0-5 years old, foodplots, rights-of-way
2.) **6 to 15 year old pine plantation stands**- unthinned only
3.) **16 to 25 year old pine plantation stands-** thinned only
4.) **Streamside management zones** (SMZ's)- major bottoms, rivers, creeks hardwood stands, and pine or hardwood SMZ's
5.) **Pine stands > 25 years old**- unburned only
6.) **Pine stands > 25 years old**- burned only
7.) **Red-cockaded woodpecker (RCW) enhancement stands**- imazapyr treatment followed by growing season burn in mature stands >25 years old

The DOQQ's and landcover shapefiles for all 4 years were overlayed with a shapefile consisting of 60 points (callcount monitoring stations) with UTM coordinates, which were used during the aforementioned breeding male count surveys. To determine effects of landscape composition and configuration on distribution and abundance of calling male bobwhites, circular buffers at a 200m radius were created around each of these points using the buffer wizard extension in ArcView 3.3. This buffer distance was chosen because of the inability to hear male bobwhites calling at distances greater than 200 meters through relatively dense pine stands. Within the circular buffers associated with each station, the proportion of habitat metrics (habitat type and configuration) was determined. Landscape and class-level habitat metrics were then calculated within the spatial scale (200m radius) for each respective call survey station using the Patch analyst extension tool (Elkie et al. 1999) in ArcView 3.3. Roseberry (1982) determined that habitats surrounding each call monitoring station can be used to determine the response of bobwhites to landscape modifications and configuration.

A logistic regression using the stepwise selection method was designed in Proc Logistic (Proc Logistic, SAS Institute Inc., Cary, North Carolina 2002) to determine significant landscape and class-level habitat variables associated with each calling station. The proportion of habitat characteristics and configuration within the 200m spatial scale was then entered into the logistic regression model to examine the distribution and abundance of calling male bobwhites relative to the habitat characteristics associated with each call count station. A binary ordered value of 0 (no bobwhite heard calling) or 1 (bobwhite heard calling) was assigned to each station.

A total of 16 variables resulting from the Patch analyst extension output in ArcView 3.3 were then entered into the models as follows: Number of Patches (NUMP), Mean Patch Size (MPS), Median Patch Size (MEDPS), Patch Size Coefficient of Variation (PSCOV), Patch Size Standard Deviation (PSSD), Total Edge (TE), Edge Density (ED), Mean Patch Edge (MPE), Mean Shape Index (MSI), Area Weighted Mean Shape Index (AWMSI), Mean Perimeter-Area Ratio (MPAR), Mean Patch Fractal Dimension (MPFD), Class Area (CA) for class-level analysis only, Area Weighted Mean Patch Fractal Dimension (AWMPFD), Shannon's Diversity Index (SDI), and Shannon's Evenness Index (SEI); (Elkie et al. 1999). All of the aforementioned landscape metrics for each call survey station were analyzed at the landscape and class-level within the 200m spatial scale.

To provide a relative measure of model fit, we generated a Hosmer-Lemeshow statistic (Hosmer and Lemeshow 1989) using the LACKFIT option in SAS (Allison 1999). All statistical procedures were performed using SAS 9.1 and tested at $\alpha = 0.05$ significance level.

RESULTS

Bobwhite Calling Census

A total of 684 calling male bobwhites were heard during call count surveys on JBWMA during the years 2002-2005. The number of males recorded in each year were as follows: 2002 (n= 135), 2003 (n= 131), 2004 (n= 229), and 2005 (n= 189). The frequency of calling male bobwhites increased in subsequent years, especially in areas where RCW treatments were implemented (Figure 3.1).

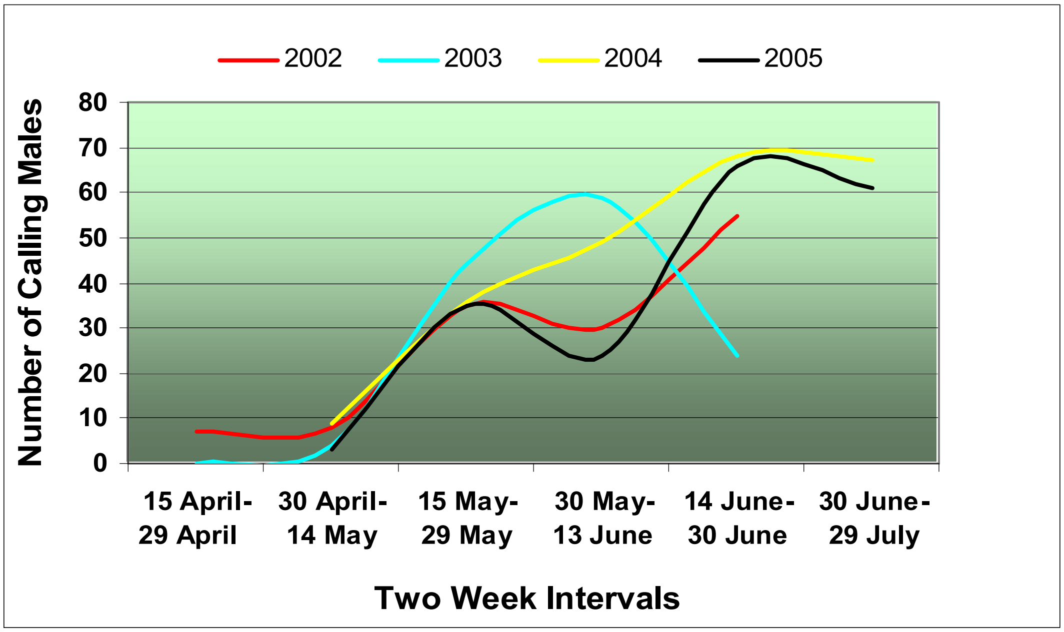

Figure 3.1. Frequency of calling male bobwhites in two week intervals during the breeding season (April-July) on Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Landscape and Class-Level Analysis

A total of 240 call-count monitoring stations were sampled during the breeding season (May-July) 2002-2005 to develop a model for the occurrence of bobwhites relative to landscape and class-level habitat characteristics. No bobwhites were detected at 113 stations during the sampling period, whereas bobwhites were detected at 127 stations.

The landscape-level model was designed to determine habitat characteristics at a course scale, irrespective of habitat type, within the 200m spatial buffer associated with each call monitoring station. In the landscape-level analysis, 9 observations (stations) were not included in the construction of the model because the landscape within them contained only 1 habitat patch type, and hence landscape metrics such as edge were not relevant. Three parameters were retained in the model: an intercept term (β = 0.55, SE =

0.96, $\chi^2 = 0.34$, $P = 0.56$), SDI ($\beta = 2.65$, SE = 0.61, $\chi^2 = 19.15$, $P < 0.001$), and SEI ($\beta = -3.46$, SE = 1.28, $\chi^2 = 7.28$, $P = 0.007$). Probability of occurrence of bobwhites was related positively to increasing patch diversity, but negatively to evenness in the distribution of patch types (Table 3.1). The landscape-level model correctly classified 68% of sites where bobwhites were detected and 48% of those where they were not.

The class-level model was designed to determine habitat characteristics at a fine scale, including each individual habitat type, within the 200m spatial buffer associated with each call monitoring station. In the class-level analysis, all 240 observations were included in the construction of the model and six parameters were retained: an intercept term ($\beta = -0.46$, SE = 0.22, $\chi^2 = 4.30$, $P = 0.04$), number of early successional patches (NUMP_1; $\beta = 0.68$, SE = 0.18, $\chi^2 = 14.37$, $P = 0.0002$), class area of thinned 16-25 year old pine plantation (CA_3; $\beta = -1.66^{e-6}$, SE = 5.83^{e-7}, $\chi^2 = 8.08$, $P = 0.0045$), patch size coefficient of variation of mature, >25 year old, unburned pine plantation (PSCOV_5; $\beta = -0.03$, SE = 0.01, $\chi^2 = 6.20$, $P = 0.01$), mean patch fractal dimension (edge complexity) of mature, >25 year old, unburned pine plantation (MPFD_5; $\beta = 2.17$, SE = 0.69, $\chi^2 = 9.67$, $P = 0.0019$), and area-weighted mean shape index of RCW enhancement stands (AWMSI_7; $\beta = 0.92$, SE = 0.35, $\chi^2 = 7.02$, $P = 0.0081$). Probability of a bobwhite occurring at a particular point was positively related to increasing numbers of patches of early successional habitats, increasing edge complexity of unburned mature pine stands, and increasing edge complexity associated with RCW stands (Table 3.2). Alternatively, the probability of a bobwhite occurring at a particular point was negatively associated with increasing amounts of 16-25 year old pine plantation that had been thinned and the amount of variation in unburned mature pine stands (Table 3.2). The class level model

Table 3.1. Landscape-level mean habitat metrics, with their associated standard errors, for 200 meter radius buffers on stations where bobwhites were detected (Bird = 1) and were not detected (Bird = 0) at Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Bird = 0

Variable[a]	Mean	Std. Error	Lower 95%	Upper 95%
NUMP	5.74	0.25	5.24	6.23
MPS (ha)	310402.27	22166.97	266481.26	354323.28
MEDPS (ha)	194428.85	25056.87	144781.88	244075.83
PSCOV (ha)	95.81	3.45	88.99	102.64
PSSD (ha)	248093.18	11229.95	225842.47	270343.89
TE (m)	10779.18	274.55	10235.19	11323.16
ED (m / ha)	0.01	0	0.008	0.01
MPE (m / patch)	2123.02	60.93	2002.29	2243.75
MSI	1.22	0.011	1.19	1.24
AWMSI	1.15	0.01	1.13	1.18
MPAR	0.032	0.004	0.03	0.04
MPFD	1.04	0.002	1.03	1.04
AWMPFD	1.02	0.002	1.02	1.02
SDI	0.84	0.03	0.78	0.9
SEI	0.86	0.01	0.83	0.88

Bird = 1

Variable[a]	Mean	Std. Error	Lower 95%	Upper 95%
NUMP	6.94	0.26	6.42	7.45
MPS (ha)	236193.85	11060.13	214306.17	258081.52
MEDPS (ha)	116359.68	9002.69	98543.92	134176.03
PSCOV (ha)	99.16	2.68	93.86	104.46
PSSD (ha)	228182.13	11617.16	205192.11	251172.15
TE (m)	12037.57	302.12	11439.68	12635.47
ED (m / ha)	0.01	0	0.01	0.01
MPE (m / patch)	1878.86	37.23	1805.18	1952.53
MSI	1.23	0.01	1.21	1.25
AWMSI	1.15	0.01	1.13	1.17
MPAR	0.03	0.003	0.03	0.04
MPFD	1.04	0.002	1.03	1.04
AWMPFD	1.02	0.001	1.018	1.02
SDI	1.01	0.03	0.96	1.06
SEI	0.85	0.01	0.83	0.87

[a] Landscape metrics are reported in (ha) hectares, (m) meters for specified variables, whereas other variables are index values and contain no units.

correctly classified 70% of sites where bobwhites were detected and 64% of sites where no bobwhites were detected. Data conformed to the logistic distribution (Hosmer-Lemeshow statistic) for both 200 meter models (landscape level - χ^2 = 7.57, df = 8, P = 0.48; class level - χ^2 = 13.23, df = 8, P = 0.10).

Table 3.2. Significant class-level mean habitat metrics, with their associated standard errors, for 200 meter radius buffers on stations where bobwhites were detected (Bird = 1) and were not detected (Bird = 0) at the Jackson-Bienville Wildlife Management Area, Louisiana, 2002-2005.

Bird = 0

Variable[a, b]	Mean	Std. Error	Lower 95%	Upper 95%
NUMP_1	0.4	0.06	0.3	0.53
CA_3 (native map units)	260319.81	36567.39	187866.21	332773.4
PSCOV_5 (ha)	9.39	2.61	4.22	14.55
MPFD_5	0.14	0.03	0.07	0.2
AWMSI_7	0.1	0.03	0.03	0.15

Bird = 1

Variable[a, b]	Mean	Std. Error	Lower 95%	Upper 95%
NUMP_1	0.98	0.09	0.8	1.17
CA_3 (native map units)	85060.85	17577.66	50275.18	119846.51
PSCOV_5 (ha)	10.39	2.24	5.96	14.82
MPFD_5	0.36	0.04	0.27	0.45
AWMSI_7	0.32	0.05	0.22	0.41

[a] Due to the number of class-level variables, only significant ones that were retained in the stepwise model are reported in this table.
[b] Class-level metrics are reported in (ha) hectares, (m) meters for specified variables, whereas other variables are index values and contain no units.

DISCUSSION

The purpose of this project was to develop a GIS-based model that could be applicable in pine plantation forests across the southern United States. The model was used to identify landscape features such as the amount of edge, stand age and patch types, burned and other managed areas, or early successional plant communities that bobwhites are associated with in order to be able to predict bobwhite occurrence within these pine

forest systems. With the use of this model, these features could be identified and used by wildlife biologists to implement landscape-level management decisions in areas known to contain bobwhites. This model would not only save time from repeated annual call count surveys, but should accurately predict bobwhite occurrence and population status in pine plantation forests based on landscape and class-level habitat features.

Our landscape-level analysis determined that the probability of occurrence of bobwhites at a station was related positively to increasing patch diversity, but negatively to evenness in the distribution of patch types. Given the current timber management regime on JBWMA, compartmental-sized areas are harvested and managed, creating large tracts of relatively homogenous habitat containing an advanced woody succession component in the understory. Many studies have reported that bobwhites require a diverse, patchy habitat that includes early successional areas of herbaceous vegetation, grassy areas for nesting purposes, patchy heavy brush or woody cover areas, and bare ground with little to no litter cover for foraging (Stoddard 1931, Stoddard 1962, Roseberry and Sudkamp 1998). The juxtaposition of these required habitat features within pine plantation landscapes is essential for bobwhite occurrence, use, and survival.

At the class-level, bobwhite occurrence was influenced by several habitat characteristics. The occurrence of bobwhites was positively influenced by increasing amounts of early successional habitat and increasing amounts of edge complexity associated with 2 types of mature pine stands (unburned and RCW). Early successional habitats have long been associated with high abundances of bobwhites (Stoddard 1931), but the 2 mature pine stands probably provided good escape cover (unburned-mature stands) and quality foraging and brooding habitats (RCW stands) (Fuller 1994). The

occurrence of bobwhites was negatively associated with 16-25 year old pine plantation stands that had been thinned, and the amount of variation in patch size of unburned mature pine stands. Thinned pine plantations on JBWMA offered very little cover and poor quality foraging, nesting, and brooding habitats. This management regime includes mechanical thinning only, with no residual treatment of fire or imazapyr. In Mississippi, Burk et al. (1990) concluded that hen turkeys with broods extensively utilized pine plantations that had been thinned followed by burning within 1-2 years, and almost entirely avoided areas not burned for more than two years. The increasing amounts of variation in patch size of unburned mature pine stands may simply be a function of some stands being small and others large and most likely just a consequence of the lack of variability in stand sizes given the timber management regime on JBWMA.

Land managers have a difficult time determining bobwhite abundance, distribution, and habitat associations in forested areas based on annual calling male census data alone. Cyclic weather patterns and other man-made disturbances such as fire, herbicide-site treatments, and mechanical timber harvest can alter landscapes and cause population fluctuations. The development of this GIS-based spatial analysis model, which can predict the presence or absence of suitable habitat and landscape configurations commonly associated with bobwhites in intensively managed pine plantation forests could prove to be very useful to wildlife land managers. Schairer et al. (1999) proposed that understanding the detailed spatial arrangement of bobwhites at the landscape-level scale could serve as a tool to quantify amounts of high and low quality habitat over time caused by changing land-use patterns and habitat management programs. We hope that the use and future development of this model could aid land managers in interpreting and

planning landscape-level management decisions based in areas that have the potential to become quality habitats suitable for bobwhites.

Management Implications

Managers need to focus on landscape-level habitat management rather than the historic small-scale management regimes, which serve only to isolate suitable habitat patches. In the future, smaller irregular shaped tracts (not compartmental-sized tracts) could be periodically burned or harvested to allow for the retention of patchy escape cover and heterogeneity of successional stages across the landscape. In other mid-rotational loblolly stands where natural succession is advanced, these tracts could be sprayed with imazapyr and followed up with maintenance fire regimes to reduce the amount of woody understory succession increasing the amount of usable space for bobwhites in an area. Guthery (1997) stated that the goal of habitat management for bobwhites should be to make all points on an area useable by bobwhites at all times, or increasing the amount of usable space, so as to provide for the maximum expression of their demographic potential.

One of the primary factors contributing to the loss of habitat for early successional species such as the bobwhite, which require widely spaced pine forests with distinct grassland communities, is hardwood encroachment associated with fire suppression (Brennan et al. 1998). The positive relationship between bobwhite occurrence and RCW management that was detected by our model provides some insight as to the management regimes needed within mature stands of pine containing advanced natural succession. Intensive management of RCW colonies includes the maintenance of low basal area mature pine forests using short rotation (1-3 years) mowing and burning

regimes in conjunction with herbicide treatments to reduce encroachment of woody species (Bowman et al. 1999). This active management regime creates, maintains, and restores the open park-like pine savannah habitats, once common in pre-settlement times and essentially absent in the late twentieth century, where species such as the RCW and bobwhite once inhabited (Wilson et al. 1995). Obviously, widespread landscape-level imazapyr application to compartmental-sized stands can be very expensive and eliminate needed escape cover for bobwhites. We suggest applying fall treatments of imazapyr in strips or small juxtaposed patches within mature stands in a landscape where succession is advanced to the point where fire alone could not improve them. Imazapyr treatments then need to be followed up with a growing season burn to eliminate residual dead stems and remove excess litter layers. This system should prove cost efficient, provide bare ground for foraging, as well as retain the patchy, woody escape cover needed to protect bobwhites from predators.

Pine forests managed for bobwhites need extensive disturbance regimes to retain the early successional herbaceous composition of their understories. Maintaining stands for long periods, post-imazapyr application, will require short prescribed burning rotations of 2 to 3 years. Incorrect burning regimes can be as bad as not burning at all; hence, fire treatments that eliminate the nesting and escape cover components of a habitat will actually do more harm than good (Stoddard 1931, Rosene 1969). Once the advanced hardwood succession in the stands is under control, managers may choose to consider using mechanical methods such as strip disking in the spring or fall following burning treatments to promote bare ground and herbaceous plant germination for bobwhite broods. Additional research is needed to evaluate the appropriate size, shape, and

juxtaposition of restored stands throughout landscapes. Also, long term research using GIS modeling at multiple spatial scales is recommended to encapture local population responses to landscape level pine-grassland restoration in pine plantation forests in order to formulate effective management plans for improving degraded bobwhite habitats.

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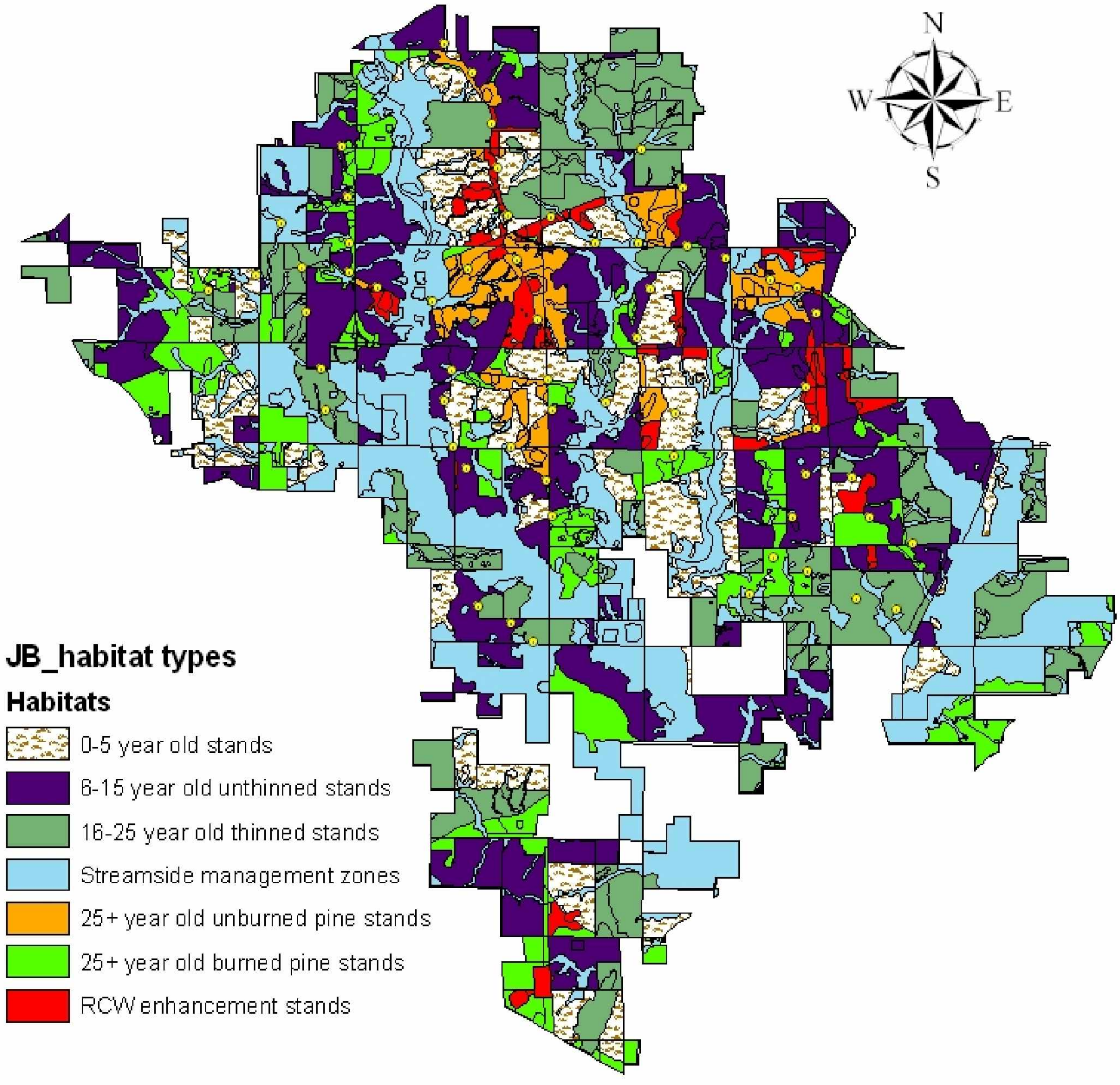
Appendix: Jackson-Bienville Wildlife Management Area Habitat Types and Call Count Stations 2005



VITA

Jason Douglas Burke was born in Durham, North Carolina on October 18, 1976 to Gary and Susan Burke. Jason grew up in Durham where his primary interest was playing baseball. Baseball tournaments took him around many different states and countries such as Japan and China to play. He was introduced to bream fishing at the age of 8, and dove hunting at the age of 12 by his father. Jason's recreation in the outdoors grew throughout high school and expanded to deer/squirrel hunting and largemouth bass fishing.

Jason's interests with wildlife biology and the outdoors soon led him to pursue the art of taxidermy. After completing his taxidermy certification classes in 1997, he opened his own business called "Burke's Taxidermy." Jason's private business was just the beginning of his endeavors, and soon after he decided to return to school. He attended Haywood Community College in western North Carolina, where he received an Associate in Applied Science degree in Fish and Wildlife Management in 2001. At Haywood Community College, Jason worked with red-cockaded woodpeckers, northern flying squirrels, and was elected president of the student chapter of the Wildlife Society.

After completing his two-year degree, Jason decided to transfer to the University of Tennessee, Knoxville where he completed his Bachelor of Science degree in Fish and Wildlife Science in May of 2003. In his tenure at the University of Tennessee, he worked as a research technician on ruffed grouse management in western North Carolina and as a research technician evaluating warm season grass re-establishment across the state of Tennessee and its effects on grassland bird populations. Jason was again elected student chapter president of the Wildlife Society at Tennessee and graduated with honors.

After completing his Bachelor of Science degree, Jason took a job with a private wildlife damage management business located in Knoxville, Tennessee called "Varmint Busters." He gained valuable experience learning trapping and exclusion techniques for nuisance wildlife, how to work with the public on these issues, and of course a broad knowledge about a variety of wildlife species. He spent his free time largemouth bass fishing on local lakes in Tennessee, and fulfilling his leisurely passion of spring wild turkey hunting.

Jason applied for graduate school at the Louisiana State University in Baton Rouge in spring of 2004, where he accepted a research assistantship studying northern bobwhite ecology and management under the direction of Dr. Michael Chamberlain. He spent nearly 2.5 years teaching dendrology, studying the ecology and management of bobwhites in pine plantation forests of north-central Louisiana and working with various wildlife research projects pertaining to: waterfowl, Louisiana black bears, Henslow's sparrows, and wild turkeys. His leisure time activities included duck hunting in the Atchafalaya River with Mike and spotted sea trout/ red drum fishing with fellow graduate students in the Breton sound area southeast of New Orleans, Louisiana. Jason started a career with Westervelt Wildlife Services as a wildlife biologist/hunting lease manager in June of 2006 and will be awarded the degree of Master of Science in Wildlife in December of 2006.