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HABITAT SELECTION BY NORTHERN BOBWHITE BROODS IN PINE SAVANNA ECOSYSTEMS

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ABSTRACT

Habitat for northern bobwhite (*Colinus virginianus*) broods is a critical component of bobwhite management. Research within pine (*Pinus* spp.) savannas has provided contradictory results regarding the value of macro-habitats with studies demonstrating selection for annually-disked fallow fields and others showing avoidance of fields and selection for burned pine savannas. Field establishment (up to 30% of a property) is a published management recommendation for bobwhites in pine savannas but there are significant annual costs with fallow-field management; information on factors that influence habitat selection by broods can improve management recommendations and facilitate weighing costs/benefits. We examined 2nd and 3rd order habitat selection by 466 broods on 3 sites during 1999–2009. All sites had similar macro-habitats (e.g., pine savanna, fallow fields, hardwood drains) but differed in soil characteristics and species composition of ground vegetation. Annually-disked fields were preferred by broods in most years on sites with predominantly grass and hardwood scrub ground vegetation. Rainfall mediated use of hardwood drains and burned upland pine savannas; hardwood drains were used more during droughts whereas burned pine savannas were used more with increased rainfall. Burned upland pine savanna was preferred on higher fertility sites in 9 of 10 years at the 3rd order level, fields were avoided or used according to availability in 8 of 10 years, and drains were avoided. Managers should consider how soil, weather, and vegetation community in pine savannas influences habitat use by bobwhite broods when identifying the value of different macro-habitats. Field establishment may or may not provide brood habitat depending on site.

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Key words: broods, chicks, *Colinus virginianus,* fields, fire, habitat use, northern bobwhite, pine, savanna

INTRODUCTION

High survival of chicks is critical to sustaining populations of northern bobwhites on managed lands; thus, creating habitat for broods is an important management consideration (Stoddard 1931, Hurst 1972, DeVos and Mueller 1993). Inadequate brood habitat, and resulting low chick survival, in bobwhite management (Burger 2001) is considered a major potential limiting factor for populations (Yates et al. 1995, Sandercock et al. 2008). Habitat for bobwhite chicks is enhanced by insect-rich herbaceous/shrub plant communities that provide cover while maintaining an open structure at ground level to facilitate foraging (Stoddard 1931, Taylor and Guthery 1994, Taylor et al. 1999). Broods also require loafing and roosting areas typically provided by woody plants, such as shrubs and vines (Taylor and Guthery 1994). Researchers in pine savanna ecosystems have shown broods select for annually-disked fields composed of annuals, such as common ragweed (*Ambrosia artemisiifolia*) or showy partridge pea (*Chamaecrista fasciculata*) (Yates et al. 1995, Carver et al. 2001). Maintaining up to 30% of pine woodlands in 1–2 ha annually-disked agricultural fields is a recurring management recommendation (Yates et al.

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1995, Michener et al. 2000, Burger 2001:139). Conversely, researchers have also found burned woodlands provide suitable brood habitat in pine savanna ecosystems (Carver et al. 2001, Hammond 2001). Creating and maintaining fields is expensive and managers should be confident fields are necessary prior to including them in land management strategies.

Vegetation types that provide suitable brood habitat for bobwhites in pine savannas may be related to soil fertility, previous land use history, timber density, and fire frequency which in turn affect groundstory plant community composition and structure (Glitzenstein et al. 2012). Information on brood habitat selection on sites that differ in respect to these properties may provide insight into habitat characteristics bobwhites select and management actions that provide suitable brood habitat under different site conditions. Rainfall interacts with soil fertility and influences plant growth after disturbance which may affect macro-habitat selection by broods. We studied brood habitat selection on 3 sites with similar habitat management practices but distinctly different 'old field' plant communities to understand the role of site-specific characteristics and precipitation on brood habitat over 4 to 10 years.

STUDY AREA

We conducted field research on Tall Timbers Research Station (TTRS), Pineland Plantation, and Sehoy Plantation. TTRS (1,568 ha) is in Leon County, Florida, and had a loblolly pine (*Pinus taeda*) and shortleaf pine (*P. echinata*) mature overstory (66%) intermixed with hardwood drains and hammocks (21%), and fallow fields (13%) 0.4 to 1.2 ha in size. Ground story communities were about equal proportions of grasses, forbs, and shrubs typical of 'old-field' plant communities (Carver et al. 2001). Herbaceous ground cover was a mix of warm season grasses and a diverse legume and forb community (Hammond 2001). Soils on TTRS are of the Fuquay-Orangeburg-Faceville series which are characterized as well-drained, moderately-fertile, fine-loam soils with varying levels of sand and clay. These soils are considered well-suited to agriculture, forestry, and pasture. Fallow fields were annually-disked in January to produce ragweed, partridge pea, and other annuals (hereafter annually-disked fields) or were undisturbed for up to 3 years to encourage development of grasses and blackberry (*Rubus* spp.). Some fallow fields were planted to longleaf pine (*P. palustris*) during the study but had vegetation characteristics similar to fallow fields and were classified as fallow fields.

Pineland Plantation in Baker County, Georgia was ~ 5,630 ha of a mixture of upland pine forests, primarily slash pine (*P. elliotti*) with intermittent live oaks (*Quercus* spp.). Each year ~ 50% of the study area was burned. Soils on Pineland are primarily Orangeburg-Lucy-Grady and Norfolk-Wagram-Grady complexes typified as sandy-loam, moderately permeable with low natural fertility. Twenty percent of the site was annually-disked fields composed primarily of ragweed. Field management has varied over the study period. Fields were harrowed in September and October, harrowed again in February, and fertilized in April to maximize growth of ragweed. Fields were no longer fertilized beginning in 2006, but some were deep plowed to break a hardpan and bring clay content to the surface to help hold moisture and promote plant vigor.

Sehoy Plantation was in northern Bullock County and southern Macon County in east-central Alabama. The study area was ~ 972 ha and was involved in an intensive quail management program for > 10 years. Soils associated with upland pine woodlands are primarily Black Belt clayey soils. Hardwood drains were associated with poorly-drained clayey and loamy soils. Loamy terrace soils were found in transitional areas between the upland and hardwood habitats. Soils are generally of low fertility and acidic with poor suitability for pasture or cultivated crops. Pine forests covered 70% of the area and were of shortleaf, longleaf, loblolly, and slash pines. Ground story communities were primarily broomsedge (*Andropogon virginicus*) as well as a variety of other bunch grasses (*Andropogon* spp.). Other evident herbaceous plants included crown grasses (*Paspalum* spp.), partridge pea, butterfly pea (*Clitoria mariana*), and a variety of *Desmodium* species. Annually-disked fields ranging from ~ 0.5 to 3 ha were composed of ragweed and made up 16% of the site. Hardwood drains (4%) were thinned prior to the study with ~ 90% of hardwoods removed. These drainages were burned each year to maintain a rich herbaceous ground cover.

METHODS

Field Procedures

Bobwhites were captured in January and March using standard walk-in funnel traps (Stoddard 1931). We assigned gender and age class, weighed each captured bobwhite, and attached a uniquely-numbered aluminum leg band (National Band and Tag Co., Newport, KY, USA). We selected 2–3 bobwhites from each captured covey to be fitted with a 6-g radio transmitter (American Wildlife Enterprises, Monticello, FL, USA and Holohil Systems Limited, Carp, ON, Canada). Trapping, handling, and marking procedures were consistent with Palmer and Wellendorf (2007) and followed the guidelines of the Tall Timbers Research Inc. Institutional Animal Care and Use Committee Permit (# GB2001-01).

Radio-marked bobwhites were located 5 times per week during the nesting season (15 Apr-1 Oct) to locate nests. We documented nesting when locations were unchanged for 2 consecutive days. Broods were located once per day after hatching until 21 days of age. Only data through 14 days of age were analyzed on Sehoy. We located radio-marked individuals with broods using homing procedures (White and Garrott 1990) and plotted locations on detailed landcover maps developed in ArcGIS (ESRI, Redlands, CA, USA). The precision of calculated locations to actual coordinates of radio-marked bobwhites was not formally tested; we thoroughly trained technicians on use of the homing technique to ensure locations were defined within at least a 30-m^2 area. We verified the correct macro-habitat landcover type (e.g., burned upland, unburned upland, field, hardwood drain) was assigned to the location.

We recorded daily rainfall totals on Pineland and TTRS but not Sehoy. We summed rainfall totals for April through June and compared these rainfall totals to habitat selection ratios for broods on these study areas.

Statistical Analyses

We computed a fixed-kernel home range for broods on TTRS and Pineland using a bivarate normal (Gaussian) kernel density estimator (HRT: Home Range Tools for ArcGIS; Version 1.1; Rogers et al. 2007) in ArcGIS 9.3. Bandwidth (*h*) was calculated for all broods using a least-squares cross-validation procedure (LSCV) for each year (Calenge 2006). Home ranges that did not converge were removed from further analysis. We estimated the median h_{lscv} value for all remaining home ranges for each year and this value was used as the bandwidth value for all home range calculations (Kenward 2001). We used a grid cell size of 10 m for the raster portion of the kernel home range procedure, which we estimated to be an appropriate scale for bobwhites, considering location resolution. We calculated a 95% volume contour from the grid that was produced, which was used in the habitat use analysis. Quail home ranges were calculated using the minimum convex polygon (MCP) method on Sehoy (Crouch 2010). We recognize that home ranges estimated using fixed-kernel method for broods on Pineland and TTRS may be larger than MCP used for broods on Sehoy (Kenward 2001). We do not believe differences in home range methodology among sites posed an issue for our study comparing habitat selection within study areas.

We categorized major habitat types on each study area to include pine woodlands burned that year, pine woodlands burned the previous year, hardwood drains, and annually-disked fields. Additional habitats on TTRS included marsh and fallow fields that were not annually disked. We followed Neu et al. (1974) using Resource Selection for Windows (Leban 1999). Second and 3rd order selection (Johnson 1980) were used to compare habitat use and availability for each year. We calculated habitat availability each year for 2nd order analysis by creating a 200-m buffered MCP polygon that encompassed all radio-marked bobwhite locations for that year. The buffered MCP was intersected with the annual landcover map to generate an overall proportion for each habitat. Second-order habitat use was defined as the proportion of each habitat type within the individual home ranges. Habitat use for 3rd order analysis was the proportion of telemetry locations within each habitat type; habitat availability was defined as the proportion of each habitat type inside the home range polygon of each brood (Neu et al. 1974). Second order analysis compared home range selection to available habitat for each individual brood and 3rd order analysis compared use of habitats to their availability within home ranges to measure habitat preference (Johnson 1980). Chi-square goodness-of-fit tests were calculated for both 2nd and 3rd order selection (Neu et al. 1974).

RESULTS

We monitored habitat use of 466 broods on 3 study sites during 1999–2009. Broods on Pineland Plantation ($n = 167$) used fields (43% of brood locations) more than pine woodlands burned that year (30% of locations) or burned the previous year (23% of locations). Annually-disked fields on Pineland were selected by broods in 8 of 9 years at the 2nd and 3rd order and used equal to availability in 1 year. Upland pine woodlands burned the previous year were avoided in 7 of 9 years at the 2nd order and used equal to availability in 2 years. Upland pine woodlands burned the previous year were avoided in 7 of 9 years at the 3rd order, selected in 1 year, and used equal to availability in 1 year. Burned pine woodlands were used less than available in 4 of 9 years and selected in 2 years at the 2nd order. Burned pine woodlands were selected in 1 of 9 years and used less than available in 6 years at the 3rd order. Amount of rainfall during April through June on Pineland was positively correlated with use of pine woodlands burned that year ($r = 0.59$, $P = 0.09$) but not use of fields ($r = –0.08$, $P = 0.83$). Brood use of pine woodlands burned that year in 2007, a severe drought year, was lowest (9% of locations) relative to other years (range = 15 to 54% use). Broods used pine woodlands burned the previous year more in 2007 (54% of brood locations) compared to other years (range = 4 to 32% use).

Broods on TTRS ($n = 240$) used pine woodlands burned that year (52% of brood locations) most followed by pine woodlands burned the previous year (27% of locations), annually-disked fields (6.2% of locations), fallow fields (5.8% of locations), and drains (2.9% of locations). Broods selected annually-disked fields in 3 of 10 years and used fields equal to availability in 7 years at the 2nd order. Broods selected annually-disked fields in 2 of 10 years and used fields equal to availability in 6 years at the 3rd order. Pine woodlands burned that year were selected in 7 of 10 years, avoided in 1 year, and used equal to availability in 2 years at the 2nd order. Pine woodlands burned that year were selected in 9 of 10 years and used equal to availability in 1 year at the 3rd order. Pine woodlands burned the previous year were avoided in 4 of 10 years and selected in 2 years at the 2nd order. Pine woodlands burned the previous year were avoided in 5 of 10 years and selected in 2 of 10 years at the 3rd order. The 2007 year had a severe drought and pine woodlands burned the previous year were selected at both the 2nd and 3rd orders. Hardwood drains were avoided in all years, except at the 2nd order in 2007 when they were used equal to their availability. Fallow fields with and without pines were selected in 6 of 10 years at the 2nd order and in 1 of 10 years at the 3rd order. Amount of rainfall was not correlated with use of fields or pine woodlands burned that spring; however, the selection ratio of hardwood drains was negatively correlated with rainfall ($r = -0.56$, $P = 0.09$).

Broods on Sehoy Plantation ($n = 59$) used annually-disked fields (37% of brood locations) most followed by pine woodlands burned the previous year (29% of locations), pine woodlands burned that year (15% of locations), and drains (14% of locations). Broods selected annually-disked fields in 3 of 4 years at the 2nd and 3rd orders. Pine woodlands burned that year were avoided in 3 of 4 years at the 2nd order and 2 of 4 years at the 3rd order. Pine woodlands burned the previous year were avoided in 1 of 4 years at the 2nd order and 3 of 4 years at the 3rd order of selection. Drains were selected in 2006 which was a severe drought year on the study area.

DISCUSSION

Habitat use and selection was variable among sites and largely consistent from year to year within sites. Differences in brood habitat selection across years but within sites were related to rainfall accumulation for a given year. Brood habitat was characterized by areas with abundant herbaceous vegetation, abundant insects, ample (20–50%) bare ground, and well dispersed woody shrubs for loafing, thermal protection, and roosting (DeVos and Mueller 1993, Burger 2001). Different soil types and vegetation communities can produce suitable brood habitat. Thus, macro-habitat selection is likely to vary depending on the suitability of the micro-habitat within a site. Suitable micro-habitat conditions on soils of moderate fertility at TTRS were provided by pine woodlands burned the same year rather than annually-disked fields. Higher clay content and fertility of the soils allowed for a relatively quick resurgence of the groundstory community after fires. Areas burned in March were used by June broods and those burned later in spring were used by broods during late summer. Broods preferred more floristically-diverse open pine woodlands and used this habitat for foraging, loafing, and roosting habitat (Hammond 2001). Preference for upland pine forests over annually-disked fields has also been observed on other properties in the Red Hills region (Hammond 2001). Brood habitat is not limiting in this landscape and the addition of fields would likely reduce the amount of useable space and potentially have a negative effect on bobwhite populations (Guthery 1997).

Annually-disked fields on sites with lower soil fertility, such as Pineland and Sehoy, were highly selected in all years except during severe drought in 2006 on Sehoy when frequently-burned hardwood drains were preferred. There is evidence that bobwhite abundance on these types of soils increases with increasing amount (up to 30%) of area in fields (Michener et al. 2000). Pine woodlands burned the same year were less suitable for broods likely due to the lower overall herbaceous groundstory. The lower soil fertility and greater sand content made these soils more drought prone and lengthened the time needed for regrowth of the understory following burning in March or April. This is supported by the correlation between early spring and summer rainfall and use of burned pine woodlands. Increased use of pine woodlands burned the same year with increasing rainfall suggests that as cover increased, so did the suitability of pine forests for bobwhite broods. Rainfall may also increase insect availability in burned pine woodlands (Wolda 1978).

Bobwhite broods on both TTRS and Sehoy Plantation shifted habitat use during periods of drought (2006 on Sehoy and 2007 on TTRS). Bobwhites shifted habitat use during periods of drought to drains or pine woodlands burned the previous year (i.e., 1 year roughs). The use of pine forests burned the previous year on Pineland Plantation also increased and use of pine forests burned that same spring was the lowest recorded during the 2007 drought. We also observed bobwhites selecting for hardwood drains and wet-weather ponds, over traditional brood habitats during the 1998 drought (Hammond 2001). Managing a diversity of macro-habitat types using fire or mechanical disturbance may be important to bobwhites during periods of stress.

MANAGEMENT IMPLICATIONS

Managers developing habitat for northern bobwhites in pine savanna ecosystems should consider how soils, vegetation community, and weather may affect the suitability of frequently-burned habitats for broods. Annually-burned woodlands on sites with moderately fertile soils supporting diverse ground cover including annual and perennial forbs, grasses, and shrubs may be the most suitable habitat. Increasing abundance of fields given these habitat conditions may actually reduce bobwhite nesting, brooding, and winter habitat provided by frequently-burned pine woodlands resulting in lower bobwhite densities. Conversely, on areas with lower fertility due to sand or acidic soil chemistry, often dominated by grasses and shrubs and relatively few forbs and legumes, annually-disked fields can be a vitally important component of brood habitat. Fields managed as brood habitat fill an important gap in the annual habitat needs for bobwhites and result in higher bobwhite densities over time. However, even when annually-disked fields are provided, our study indicates burned woodlands and hardwood drains still serve as critical habitat components, such as providing shrubs for roosting as well as additional foraging habitats. Our study also indicated that frequently burned drains can be important brood habitat during drought periods. A diversity of habitat types that are frequently burned, or disked, provides the range of habitats needed to sustain bobwhites across years and under differing weather regimes.

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