National Quail Symposium Proceedings

Volume 6 | Article 30

2009

# Effects of Two Burn Scales on Northern Bobwhite Demographic Parameters and Home Range Size

Shane D. Wellendorf
*Tall Timbers Research Station and Land Conservancy*

William E. Palmer
*Tall Timbers Research Station and Land Conservancy*

# Effects of Two Burn Scales on Northern Bobwhite Demographic Parameters and Home Range Size

**Shane D. Wellendorf[1], William E. Palmer**

Tall Timbers Research Station and Land Conservancy, 13093 Henry Beadel Dr., Tallahassee, FL 32312, USA

**Properties managed for bobwhite hunting in the Red Hills region use prescribed fire to burn 40-60% of their upland areas annually. Burning large areas could negatively affect bobwhite survival by increasing predation risk. Burning small areas could influence daily habitat use patterns and may influence nesting or brooding processes. Research on how the scale of management influences home range size and demographics of bobwhites is lacking. Therefore, on Tall Timbers Research Station (TTRS) we established 4-140 ha experimental treatment areas and randomly assigned 2 areas to be burned at a small scale (∼2.25 ha burn patch size) and 2 areas to be burned at a large scale (∼8 ha burn patch size). Upland habitat areas were divided into similar size patches, depending on treatment, with half of the units in the treatment areas burned annually in an alternating pattern. We annually radio-tagged bobwhites (2003-2005) and monitored their survival, productivity, and home range size during the breeding season. In 2003-2004, the risk of mortality was higher on large scale versus small scale treatments during March-May, but there were no differences in 2005. Per capita nest production was higher on small scale areas (0.68 nests/bird) than large scale areas (0.43 nests/bird). Autumn density was higher on small scale treatment areas (3.5 bobwhite/ha, SE = 0.62) compared to large scale treatment areas (2.7 bobwhite/ha SE=0.67; $F_{1,2}$ = 12.9, *P* = 0.07). On TTRS, there were marginal benefits of small scale management for early breeding season survival and productivity, especially during years with high late winter mortality or slow vegetative growth after burning due to drought, but the gains we observed may not be enough to supersede other management priorities.**

Citation: Wellendorf SD, Palmer WE. 2009. Effects of two burn scales on northern bobwhite demographic parameters and home range size. Pages 271 - 281 in Cederbaum SB, Faircloth BC, Terhune TM, Thompson JJ, Carroll JP, eds. Gamebird 2006: Quail VI and Perdix XII. 31 May - 4 June 2006. Warnell School of Forestry and Natural Resources, Athens, GA, USA.

**Key words**: *Colinus virginianus*, fire, Florida, northern bobwhite, prescribed burning, productivity, scale of management, survival

## Introduction

Prescribed burning is an important management practice for southeastern hunting plantations managed for northern bobwhite (*Colinus virginianus*; hereafter: bobwhite; Stoddard 1931, Rosene 1969). Prescribed burning improves habitat for bobwhites by increasing bare ground, increasing availability of seeds and insects when foraging, and promoting herbaceous plants and shrubs important for cover and food (Brennan et al. 2000). To achieve these benefits, southeastern hunting plantation managers typically use prescribed fire on a regular 1-2 year interval on 40-70% of their uplands each year, a frequency and extent that is necessary to maintain upland habitat conditions suitable for bobwhites. However, the scale of burning differs; some managers burn upland areas in patch sizes of 8-20 ha (20-50 acres) or greater, while others protect small patches 0.5-2.5 ha (1-5 acres) scattered throughout the upland landscape to create a mosaic of burned and unburned habitats (Rosene 1969, Landers and Mueller 1986). Burning upland habitats at these different scales creates a matrix of different habitat conditions and varying amounts of edge between burned and unburned habitats. These varying patch configurations and the usability of these patches through time could influence important demographic parameters such as survival, productivity, and home range sizes that could influence autumn population size, the most important population variable for a hunting plantation.

Prescribed burning also can increase the short-term susceptibility of bobwhites to predation by removing protective cover and forcing movements to

[1]**Correspondence**: shanew@ttrs.org

and use of unfamiliar areas (Stoddard 1931, Mueller and Atkinson 1985, Folk 2006). The predation risk for bobwhites could likely increase as the burn area increases in size. However, if adequate cover exists within a reasonable distance or within a home range of a bobwhite, survival impacts may be minimized. Additionally, the scale of burning or patch size along with the usefulness of those patches can influence susceptibility of adults, nests, and broods to predation. As patch sizes decrease, the ability of predators to effectively forage and find prey may increase (Jimenez and Conover 2001, Wiens 1989). The effects of burning at different scales may create competing costs and benefits when managing for bobwhite abundance.

There is little information on the direct effects of the scale of burning on bobwhite survival and productivity on southeastern hunting plantations. Therefore, our objective was to compare the effects of burning at a 2 ha scale and 8 ha scale on bobwhite survival, reproductive response, home range size, and autumn bobwhite density.

## Study Area

We conducted this study on Tall Timbers Research Station (TTRS; 1,568 ha), Leon County, Florida. The landscape composition of TTRS was rolling hills consisting of primarily upland pine forests (66%) including longleaf pine (*Pinus palustris*), loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) in the overstory, and equal proportions of grasses, forbs, and shrubs associated with "old-field" plant succession in the understory. Intermixed throughout the uplands were hardwood drains and hammocks (21%) and annually disked fallow fields (13%) 0.4 to 1.2 ha in size. Prescribed fire was used throughout TTRS on a 2-year interval to control encroachment of hardwood trees and to maintain the mix of herbaceous and woody ground cover. Other management practices used in the uplands were mowing and roller chopping of hardwood and pine saplings.

As part of a separate long-term research project, TTRS was divided into 2 sides with 1 side receiving supplemental feed. Approximately 5 liters/ha of grain sorghum were spread twice monthly along designated feed trails through the uplands. Additionally, in 2004-2005, we implemented mesomammal predator reduction on the entire property between March and October, which consisted of removal of raccoons (*Procyon lotor*), opossums (*Didelphis marsupialis*), armadillos (*Dasypus novemcinctus*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), and gray foxes (*Urocyon cinereoargenteus*; University of Georgia, IACUC #: A2001-100100-0).

## Methods

### *Scale Treatments*

We selected 4-140 ha areas on TTRS with similar landscape composition; 2 areas had supplemental feeding and 2 areas had no additional feeding. Areas were randomly assigned either a large scale treatment, for which upland habitats were divided into 8 ha blocks, or a small scale treatment, for which upland areas were divided into 2.25 ha blocks (Figure 1). In 2002, on all treatment areas, blocks were selected in an alternating pattern and were burned March-April, such that half of the uplands were burned. The following year the unburned upland blocks from the previous year were burned to create a 2 year burning rotation for all upland areas. This alternating burn pattern was continued during the subsequent years of the study (2003-2005).

### *Telemetry Data*

Bobwhites were captured in January and March using standard walk-in funnel traps (Stoddard 1931). We determined sex, age class, and weight for each captured bobwhite and attached a uniquely numbered aluminum leg band (National Band and Tag Co., Newport, KY 41072). From each captured covey we selected 2-3 bobwhites to be fitted with a 6-g radio transmitter (American Wildlife Enterprises, Monticello, FL 32344). Radio transmitters were distributed at an approximate ratio of 1 radio-tagged male to 4 radio-tagged females. In January, trapping efforts and radio distributions were equally applied to all areas of TTRS, while in March trapping was

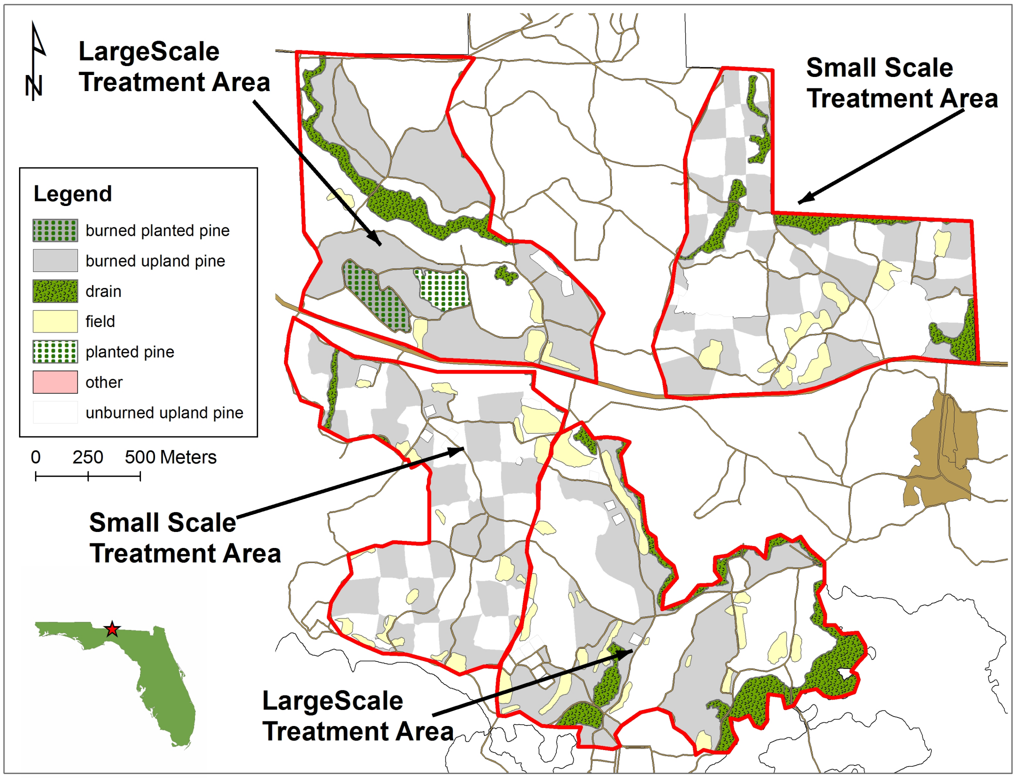


Figure 1: Small scale (2.25 ha) and Large scale (8 ha) treatment areas on Tall Timbers Research Station, Florida, USA, 2003-2005.

focused on areas with an inadequate radio tag sample. 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-tagged bobwhites were located at least once weekly until 15 April and then 3-5 times a week thereafter until 1 October. We determined locations of radio-tagged individuals using homing procedures (White and Garrott 1990) and then marked locations on detailed landcover maps developed in ArcGIS (ESRI, Redlands, CA ). While the precision of calculated locations to the actual locations of radio-tagged bobwhites has not been formally determined, we thoroughly trained technicians on the homing technique to ensure they determined locations to within at least a 30 $m^2$ area. Additionally, they verified that the correct macrohabitat landcover type (e.g., burned upland, unburned upland, field, hardwood drain) was assigned to the location.

Transmitters motionless for 12 hours changed pulse rate to notify observers of a potential mortality. Idle transmitters were located to determine if mortality had occurred or if the transmitter had slipped off of the bobwhite. All speculated radio slip observations and failed transmitters were censored from the survival analysis.

We determined that a bobwhite was nesting when its locations were unchanged for 2 consecutive days and the mortality sensor had not activated. Nesting sites were flagged and monitored daily until a depredation or hatch. Bobwhites with a hatch were treated as a brood until 14 days post hatch or until it was determined the bobwhite was no longer with a brood. We assumed that we detected all incubated nests of radio-tagged bobwhites for the productivity index, which is plausible since bobwhites were located frequently during the breeding season.

### *Autumn Covey Density*

We conducted morning covey call surveys September-November. Three 25-ha square survey quadrants were randomly located on each treatment area. An observer was located on the mid-point of each quadrant side, totaling 4 observers per quadrant. From 45 minutes before sunrise until sunrise, observers recorded bearing, estimated distance, and plotted locations of all calling coveys on maps within the quadrant and surrounding areas. All observers had practiced collecting data at least twice before participating in the surveys, and most of them had extensive experience from surveys of previous years (Wellendorf and Palmer 2005). We determined calling covey locations via biangulation or triangulation by two or more observers or locations verified by a single observer within 100 m of the calling covey. This process gave us an accurate count of all calling coveys within the 25 ha survey area and we assumed all calling coveys were accurately detected.

We calculated bobwhite density within the 25 ha area by adjusting the calling covey count by a predicted estimate of the calling rate (Wellendorf et al. 2004). This adjustment produced an estimate of the number of coveys within a grid, which we then multiplied by the average covey size from flush data collected over the entire treatment area. We used an average covey size since it was not possible to consistently flush all coveys or all bobwhites within a covey out of a particular 25 ha survey area.

### *Data Analysis*

For the survival, productivity, and home range analyses individual radio-tagged bobwhites were assigned a treatment classification (small or large scale) using telemetry locations. Within each year, bobwhites were assigned a particular treatment if more than 70% of all locations were within the boundaries of a treatment area. This arbitrary assignment yielded a dataset of radio-tagged bobwhites most affected by the treatment area where the majority of its time was spent, but did not restrict inclusion of radio-tagged bobwhites that occasionally went outside of the treatment area boundaries.

*Survival* - Given the limited sample sizes of radio-tagged bobwhite on some treatment areas for individual years and the potential biases associated with Kaplan-Meier product limit method (Kaplan and Meier 1958) when using small sample sizes (Pollock et al. 1989, Palmer and Wellendorf 2007) we selected Cox's proportional hazard modeling (Cox and Oakes 1984, SAS Institute, Inc. 2002, PROC PHREG) to investigate differences in the hazard rates for scale treatments (small, large), side (fed, not fed), and year (2003-2005). The hazard rate model relates failure times (death or censored), which is the equivalent to the instantaneous mortality rate, to the explanatory variables. We analyzed the early breeding season hazard rate, designated as 1 March-1 July, for each year. We hypothesized that burning at different scales would have the greatest effect on survival during this time period. We treated each year as independent due to the amount of time between breeding seasons and the environmental differences among years. Preliminary analyses tested for time dependence within the breeding season for each explanatory variable in the model; if we detected no time dependence for an explanatory variable, we used the main effects explanatory variable.

*Productivity* - We calculated 3 productivity parameters; a per capita female productivity index, female nest success, and a per capita female hatch index for each scale treatment each year. Observations were pooled over both sides due to limited sample sizes. The female productivity index was calculated dividing the total number of female incubated nests for a given breeding season by the number females entering the breeding season. Radio-tagged bobwhites were considered part of the breeding population if they were alive on 15 April of each year. Nest success was presented as a percentage of successful nests. Finally, we calculated the female hatch index, which the productivity index multiplied by nest success. Nests abandoned due to observer intrusion were censored from nest success calculations and the hatch index. Male nest incubation was not investigated due to limited sample sizes.

*Autumn Density* - Survey grids were sampled once and were considered sub-sample observations used to estimate a covey density treatment mean for each year. Data were analyzed using a 3 factor ANOVA (Stat Soft Inc. 2001) with 2-way interactions for the variables: scale, side, and year. Each year was treated as independent. Small sample sizes prevented us from conducting repeated measures analysis for each treatment area by year. Even though there was some unexplained variation in density associated with each specific treatment area we presume that it would have minimal effects on the treatment results.

*Home Range Analysis* - Early breeding season (1 March-1 July) home ranges were calculated for all radio-tagged bobwhites surviving until 1 July. We used surviving individuals because we wanted to investigate treatment differences in home range size over the entire period of interest, and we did not want the analysis biased by premature deaths or small sample sizes. We used all locations, including locations collected during brood-rearing and one nest site location, for home range analyses. We estimated 95% fixed-kernel home ranges using a fixed smoothing parameter ($H_{ref}$) estimate of 38, which was an average of the least squares cross-validation (LSCV) $H_{ref}$ values for all radio-tagged bobwhites during the breeding season, 2003-2005 (Kenward 2001). Home range estimates were calculated for each scale treatment each year, but were pooled by side, due to sample size concerns. Additionally, each year was treated independently due to the environmental differences between years and the length of time between calculations of seasonal home ranges.

## Results

For the hazard rate modeling analysis we monitored 33 radio-tagged bobwhite in 2003, 33 in 2004, and 46 in 2005 on the small scale treatment areas, and on large scale treatment areas we monitored 108 radio-tagged bobwhite in 2003, 40 in 2004, and 49 in 2005. We observed no statistical differences in the hazard function or instantaneous mortality rate by side for any year (Wald $\chi^2 > 1.91$, DF = 1, $P > 0.166$). The effect of scale on the hazard rate varied by years. We found no significant effects (Wald $\chi^2 > 1.53$, DF = 1, $P > 0.215$) of scale on hazard rate in 2003 or 2005. However, in 2004 bobwhites on small scale treatment areas were 2.3 times less likely to die than bobwhites on large scale treatment areas (Wald $\chi^2 = 7.91$, DF = 1, $P > 0.005$). While the scale treatment was not significant in 2003 there was a trend of a lower hazard rate in the first 60 days of the breeding season for small scale areas.

The number of radio-tagged female bobwhites alive on 15 April was 25 in 2003, 22 in 2004, and 28 in 2005 for small scale areas; on large scale areas there were 47 in 2003, 25 in 2004, and 33 in 2005. We documented 94 incubated nests for all years and treatment areas, of which 6 (6%) were abandoned due to observer intrusion (Table 1). In all years, we recorded higher nest productivity on small scale treatment areas (1.4-1.5 times larger; Table 1). However, in 2003 and 2005 we observed slightly higher nest success on large scale than on small scale treatment areas, 1.4 times larger in 2003 and 1.2 times larger in 2005. Results were varied for the female population hatch index. In 2003, hatch index was similar by scale treatments, but in 2004 and 2005 the hatch index was 1.5 and 1.3 times greater on small scale than on large scale treatment areas.

Autumn bobwhite density was $2.9 \pm 0.6$ (SE) bobwhite/ha in 2003, $2.5 \pm 1.0$ in 2004 and $3.9 \pm 0.8$ in 2005. We observed a significantly larger autumn population on the fed side ($4.33 \pm 0.48$ bobwhite/ha) than on the unfed side ($1.87 \pm 0.47$ bobwhite/ha; $F_{1,2} = 18.18$, $P = 0.008$). Additionally, there was a trend for higher autumn bobwhite density on small scale treatment areas ($3.51 \pm 0.77$ bobwhite/ha) than on large scale treatment areas ($2.7 \pm 0.82$ bobwhite/ha; $F_{1,2} = 12.89$, $P = 0.07$), but the degree of difference between treatments was variable among years (Figure 2).

We calculated March-June home ranges for 121 radio-tagged individuals, 2003-2005. The mean

Table 1: Sample sizes for radio-tagged female bobwhites alive on 15 April and their reproductive output on small and large scale treatment areas on Tall Timbers Research Station, Florida, USA, 2003-2005.

| | | Radio-tagged Females | Female Nests | Productivity Index[a] | Female nest success (%) | Hatches/female[b] |
|---|---|---|---|---|---|---|
| 2003 | LARGE | 47 | 15 | 0.32 | 60 | 0.19 |
| | SMALL | 25 | 11 | 0.44 | 42.9 | 0.19 |
| 2004 | LARGE | 21 | 13 | 0.62 | 66.7 | 0.41 |
| | SMALL | 22 | 21 | 0.95 | 66.7 | 0.64 |
| 2005 | LARGE | 33 | 15 | 0.45 | 85.7 | 0.39 |
| | SMALL | 28 | 19 | 0.67 | 73.7 | 0.5 |

[a] Total number of incubated nests for a breeding season / female radio-tagged sample alive on 15 April

[b] Total number of female incubated nests * female nest success / female radio-tagged sample alive on 15 April / 100

number of radio locations used per individual was 49.1 (SE = 1.6; range: 18-92). We observed a significant interaction between side and year ($F_{2,111}$ = 180.21, $P$ = 0.01), but observed no significant differences in home range size by scale ($F_{1,111}$ = 5.64, $P$ = 0.58). However, we did observe a trend for larger home ranges on large scale treatment areas in 2004 (Table 2).

## Discussion

We observed that the risk of mortality was marginally higher on large scale treatment areas during the early part of the breeding season for 2 of the 3 years. This result may have been influenced by avian predator migration patterns and abundance during the early breeding season (Mueller et al. 1988). Annual survival in 2003 and 2004 was lower than in 2001 and 2002 on TTRS (Palmer and Wellendorf 2007), which was attributed to greater proportions of avian kills of radio-tagged bobwhites during the early breeding season on TTRS (Faircloth et al. 2005, W. Palmer and S. Wellendorf, unpublished data). Radio-tagged bobwhites were observed using small patches of residual cover in burned areas soon after a fire, which is similar to findings of Mueller et al. (1988) and Carter et al. (2002), and therefore may have been more susceptible to avian predation on large scale areas due to limited proximity of thicker protective cover. An additional factor potentially increasing mortality risks to bobwhites was a decrease of cotton rat abundance, a common alternative prey (Schoch 2003), which was lower on large scale than small scale areas during the early breeding season for all years (Hannon 2006). In 2004, we observed the largest difference in mortality risk between treatments, which was associated with a below average rainfall in March and April of 2004 (Nation Weather Service, Tallahassee, FL), limiting the growth of vegetative cover in the burn blocks. The extended lack of herbaceous cover may have increased mortality risk, especially on large scale areas. In 2005, we observed similar mortality risk among treatments, associated with above normal rainfall (Nation Weather Service, Tallahassee, FL) and higher cotton rat abundance (Hannon 2006).

Prior studies have documented little or no ef-

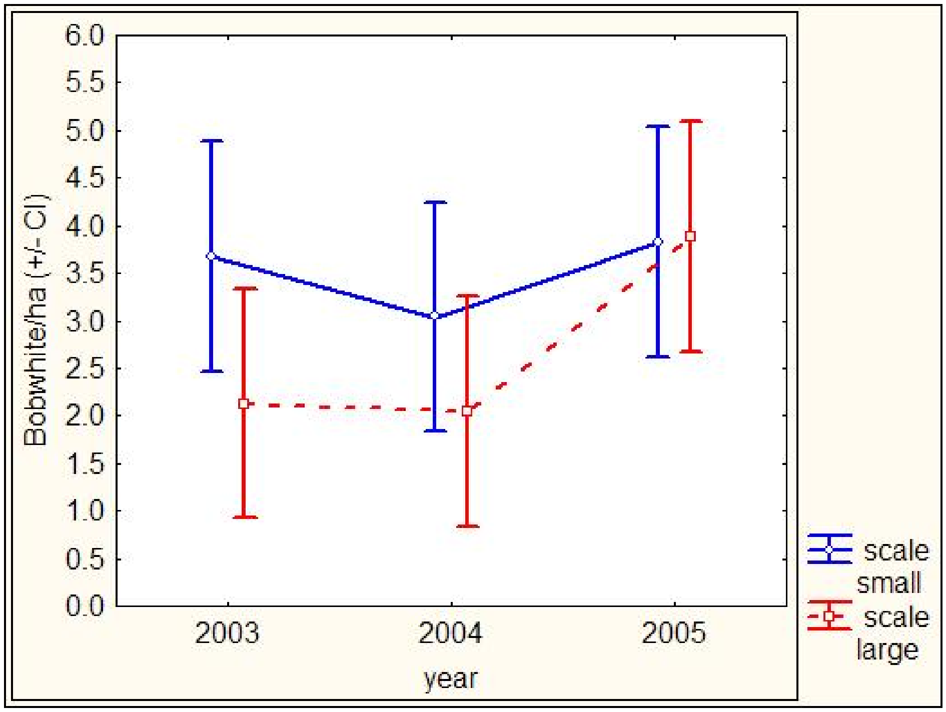


Figure 2: Autumn density of northern bobwhite by small and large scale treatment areas on Tall Timbers Research Station, Florida, USA, 2003-2005.

fect of burning on bobwhite survival. Mueller et al. (1988) documented no differences in mortality rates between clean burns and patchy burns (>100 ha) among years. Carter et al. (2002) observed no differences in survival between bobwhites in burned or unburned pastures (>60 ha). We observed an effect of burning on mortality risk during 2 years in which survival was lower than normal (Palmer and Wellendorf 2007), and we observed autumn population declines those years. Effects of burning scales on mortality risk of bobwhites may be greater during years with generally poor conditions for bobwhites, and during those years burning at small scales may improve survival. However, during relatively good years for bobwhites, such as 2005, scales of burning may not influence survival.

Small scale management may decrease nesting productivity and success due to increased search efficiency of nest predators (Jimenez and Conover 2001, Wiens 1989). Small block sizes allow for more complete searching within a block and increases the amount of edge available for predators to forage along, especially for gray rat snakes (Stapleton 2005) and mammals, such as raccoons, which are both major nest predators (Staller et al. 2005). We observed higher nest success on large scale areas in 2003 and 2005, but documented higher nest productivity for hens on small scale areas all 3 years. The hatch index, which is a combination of the 2 other factors, did not differ between treatments in 2003 and was slightly higher on small scale areas in 2004 and 2005. Most likely, the differences we observed in per capita nest production were due to differences in mortality risk during the early breeding season. The productivity index is greatly influenced by hen survival, especially during the early breeding season, which is when the highest numbers of nests are incubated (Terhune 2004). After accounting for survival, the differences in productivity between scale treatments would likely have been similar which supports the conclusion that burning at different scales would have little impact on productivity of bobwhites.

The productivity index and hatch index yield different conclusions when comparing large scale and small scale areas due to differences in nest success between areas. While the difference in nest success was greatest in 2003, it had little impact on autumn abundance, which supports the idea that nest success is a poor predictor of site productivity (W. Palmer, unpublished data). Additionally, macrohabitat conditions around the nest have little impact on nesting success. Staller et al. (2002) found no differences in macrohabitat composition around successful and unsuccessful nests on TTRS, including both burned and unburned uplands. Their results and the results from this study support the hypothesis that on intensively managed quail lands habitat composition and scale, within the range of this study may have little effect on productivity; other factors such as predator abundance may have a stronger influence on productivity (Staller et al. 2005).

We observed marginally higher autumn densities on small scale treatment areas in 2 of 3 years. The slightly lower mortality risk and improved nest productivity on the small scale areas are likely partial reasons for density differences in the scale treatments, but these factors do not fully explain the varying effect size on the scale treatments by year and other null effects. There is no definitive explanation for the density differences and other factors can affect autumn bobwhite density estimates, such as inherent sampling variability or other unmeasured population parameters including brood survival. Brood survival can have a significant impact on autumn density, and scale of burn may be an important factor, considering the importance of burned upland areas for brood habitat use (Carver 1998, Hammond 2001). Unfortunately, no information is available on brood usage in varying burn scale areas. Movements of bobwhites in and out of our treatment areas between the breeding season and at the time of the autumn covey call surveys could have also influenced our results. We make the assumption that this factor did not impact our results, which reasonable considering the relatively homogeneous habitat conditions and large proportions of usable space in early autumn. Additionally, we did not observe any post-breeding movements from our radio-tagged bobwhites that may have influenced our results.

We observed few differences in home range sizes by scale or year; whereas we had expected to see greater home range size on large scale areas. Hypothetically, upland habitats were to be considered a binomial of either useable or unusable (Guthery 1997) by bobwhites and for a period of time the burned areas would have been considered unusable. Therefore, bobwhites would have been restricted to the unburned habitats after burning and before the early growth phase of the burn blocks, which in turn would have affected home range size. However, we observed almost an immediate use of burned areas and a consistent increase in use over time, more consistent with a gradient concept of increasing habitat suitability over time. Mueller and Atkinson (1985) and Mueller et al. (1988) observed bobwhites allocating their time in burned areas within 7 days after the burn, especially in areas where some residual vegetative cover remained. On TTRS, with a diverse vegetative ground cover associated with post agricultural landscapes, burn blocks typically were a mosaic of various amounts of cover. Additional factors, such as supplemental feeding and predator control may have minimized variability in home range size (Newton 1998), which could have potentially reduced the effects of burning scales on home range sizes.

While small scale treatments had slightly higher productivity and autumn densities, the additional land management costs associated with burning at a small scale may well outweigh the additional population gains. Approximately 4 times more fire breaks were needed in the small scale treatment areas, and time for implementation of the burn was increased to protect the numerous surrounding blocks from burning. The increased disturbance associated with small scale prescribed burning may be unwanted on areas where protecting sensitive native ground cover is a concern.

Table 2: Mean home range sizes for northern bobwhite on small and large scale treatment areas on Tall Timbers Research Station, Florida, USA, 2003-2005.

| Year | Scale | *n* | Mean Home Range (ha) | SE |
|---|---|---|---|---|
| 2003 | LARGE | 29 | 16.2 | 1.1 |
| | SMALL | 12 | 13.9 | 1.3 |
| 2004 | LARGE | 18 | 17.6 | 1.7 |
| | SMALL | 17 | 12.6 | 1.3 |
| 2005 | LARGE | 22 | 14.2 | 1.1 |
| | SMALL | 23 | 14.1 | 1.7 |

## Management Implications

On Tall Timbers Research Station, which implements land management practices similar to many southeastern hunting plantations, a large proportion of the landscape is considered useable for bobwhites throughout most time periods within a year. Prescribed burning of upland areas is the primary land management tool to maintain vegetation characteristics optimal for bobwhites. However, for a short period of time after fire vegetation cover is reduced, bobwhites may be more susceptible to predation and forced to move to suboptimal habitat until cover returns. We attempted in this study to determine if we could improve survival and productivity by adjusting the juxtaposition of burned areas to unburned areas.

Overall, we observed minor differences in survival, productivity, or autumn density at the 2 management scales that we burned. On southeastern hunting plantations, either management scale would be adequate for upland habitat management for bobwhite. We recommend managing burn blocks of a size within the range of this study that is most appropriate for the landscape and other management objectives, such as adjustment of fire intensity and minimizing ground disturbance from establishing fire breaks. During years in which production is relatively poor due to early growing season droughts or excessive avian mortality, small scale burning may have some potential benefits during the early breeding season that could improve autumn density.

While the prescribed burning scales used in this experiment are typical on southeastern hunting plantations they are uncommon on public lands and other properties that manage for early successional habitats critical for bobwhites. Normally, these areas burn at scales significantly larger ranging from 100's to 1000's of hectares in size. Our results indicate that burn scales, which were considerably smaller than those on public areas, can impact bobwhite demographics on some years. Managers of other property types interested in bobwhite management should evaluate burning scales in their resource management plans and burn at the smallest scale whenever possible to improve bobwhite survival and productivity.

## Acknowledgments

We would like to thank the many graduate students, technicians, and interns that participated in the data collection. Additionally, the staff at Tall Timbers Research Station provided much appreciated logistical support. Funding for this project was from the "Joseph H. Thompson Fund", which was matched by general membership contributions to the game bird program at TTRS. J. A. Martin and R. E. Masters provided a review of this manuscript prior to submission.

## References

Brennan, L. A., J. M. Lee, E. L. Staller, S. D. Wellendorf, and R. S. Fuller. 2000. Effects of seasonal fire applications on northern bobwhite brood habitat and hunting success. Pages 66–69 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Carter, P. S., D. Rollins, and C. B. Scott. 2002. Initial effects of prescribed burning on survival and nesting success of northern bobwhite in west-central Texas. Proceedings of the National Quail Symposium 5:129–134.

Carver, A. C. 1998. Northern bobwhite brood habitat relationships in old-field vegetation in the Red Hills region of northern Florida. Master's thesis, Mississippi State University, Starkville, MS, USA.

Cox, D. R., and D. Oakes. 1984. Analysis of survival data. Chapman and Hall, London, UK.

Faircloth, B. C., W. E. Palmer, and J. P. Carroll. 2005. Variation in survival within and among northern bobwhite (*Colinus virginianus*) coveys. Pages 80–81 *in* K. Pohlmeyer, editor. Extended Abstracts of the XXVIIth Congress of the International Union of Game Biologists. DSV-Verlag, Hannover, Germany.

Folk, T. H. 2006. Population ecology of northern bobwhites. Ph.D. thesis, Auburn University, Auburn, AL, USA.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Hammond, A. 2001. Ecology and management of northern bobwhite broods in a longleaf pine-wiregrass ecosystem. Master's thesis, Mississippi State University, Starkville, MS, USA.

Hannon, T. H. 2006. Hispid cotton rat (*Sigmodon hispidus*) ecology in north Florida. Master's thesis, University of Georgia, Athens, GA, USA.

Jimenez, J. E., and M. R. Conover. 2001. Ecological approaches to reduce predation on ground-nesting gamebirds and their nests. Wildlife Society Bulletin 29:62–69.

Kaplan, E. L., and P. Meier. 1958. Non-parametric estimation from incomplete observations. Journal of the American Statistical Association 53:457–481.

Kenward, R. E. 2001. A manual for wildlife radio tagging. Academic Press, San Diego, CA, USA.

Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: A habitat approach. Miscellaneous Publication 6, Tall Timbers Research Station, Tallahassee, FL, USA.

Mueller, B. S., and J. Atkinson. 1985. First year report: Post-fire mortality study. Pages 4–5 *in* Proceedings Tall Timbers Game Bird Seminar, volume 7. Tall Timbers Research Station, Tallahassee, FL, USA.

Mueller, B. S., J. B. Atkinson, Jr., and T. DeVos. 1988. Evaluation of post-fire cover to mortality of northern bobwhites. Biotelemetry 10:254–262.

Newton, I. 1998. Population limitation in birds. Academic Press, London, UK.

Palmer, W. E., and S. D. Wellendorf. 2007. Effects of radio-transmitters on bobwhite survival and recovery rates. Journal of Wildlife Management 71:1281–1287.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: The staggered entry design. Journal of Wildlife Management 53:7–15.

Rosene, W. 1969. The bobwhite quail: Its life and management. Rutgers University Press, New Brunswick, NJ, USA.

SAS Institute, Inc. 2002. Version 9.1. SAS Institute, Cary, NC, USA.

Schoch, B. N. 2003. Diet, age, and reproduction of predators in response to intensive removal during the quail nesting season. Master's thesis, University of Georgia, Athens, GA, USA.

Staller, E. L., W. E. Palmer, J. P. Carroll, R. P. Thornton, and D. C. Sisson. 2005. Identifying predators at northern bobwhite nests. Journal of Wildlife Management 69:124–132.

Staller, E. S., W. E. Palmer, and J. P. Carroll. 2002. Macrohabitat composition surrounding successful and unsuccessful nests. Proceedings of the National Quail Symposium 5:61–64.

Stapleton, S. 2005. Snake ecology in the red hills of Georgia and Florida. Master's thesis, University of Georgia, Athens, GA, USA.

Stat Soft Inc. 2001. STATISTICA (data analysis software system), version 6. StatSoft, Inc.

Stoddard, H. L. 1931. The bobwhite quail: Its habits, preservation, and increase. Charles Scribner's Sons, New York, NY, USA.

Terhune, T. M. 2004. Two techniques of the northern bobwhite: Relocation and summer male call count. Master's thesis, Auburn University, Auburn, AL, USA.

Wellendorf, S. D., and W. E. Palmer. 2005. Investigating the use of covey call point counts to estimate autumn density of northern bobwhite. Wildlife Biology in Practice 1:140–145.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2004. Estimating call rates of northern bobwhite coveys and censusing population. Journal of Wildlife Management 68:672–682.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, CA, USA.

Wiens, J. A. 1989. Spatial scaling in ecology. Functional Ecology 3:385–397.