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# A FOCUSED HABITAT APPROACH FOR NORTHERN BOBWHITE RESTORATION IN KENTUCKY

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## ABSTRACT

The Kentucky Department of Fish and Wildlife Resources has measured northern bobwhite (*Colinus virginianus*) population trends since 1960. During that span, northern bobwhite steadily declined because clean agriculture, fescue-sod, plant succession, and development eroded habitat suitability. Multiple efforts have failed with regard to restoring northern bobwhite numbers. Over 3.5 million northern bobwhite were released by the Department over a three decade period. Habitat efforts on private lands were deployed for over 20 years with mixed results. Support for the habitat restoration efforts waned. In 2008, the Department unveiled a new strategy centered on restoring concentrated habitat in focal areas. From 2008 to 2013, the Department managed habitat and monitored breeding northern bobwhite on 5 focal areas that were distributed throughout the state. Focal areas ranged in size from 1,155 to 16,517 ha. A total of 109 breeding bird survey points were monitored annually with up to three repetitions. Habitat management activity was also tracked. We used distance sampling to model density-dependent and density-independent population growth. Across the study, there was a 0.992 probability that our populations were growing with a mean region-wide, density independent growth rate of 35.7% annually. We were able to grow populations in an array of landscapes that were dominated by agriculture and grasslands. Management actions maintaining $\geq$10% of the focus areas in early successional habitat consistently supported growing northern bobwhite populations. The unique nature of our focal areas made them poor laboratories for field study, so future multi-state collaboration may be essential to understand the factors driving northern bobwhite growth. A better understanding of northern bobwhite population growth as it relates to landscape, management, weather, and harvest metrics will improve management prescriptions for northern bobwhite habitat on larger landscapes in the future.

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The first recorded declines of northern bobwhite (*Colinus virginianus*) in Kentucky were reported in 1917 (Kentucky Game and Fish Commission 1975). Harsh winters and eroding habitat conditions reduced populations to levels that motivated the first attempts at restocking. By 1930, roughly 100,000 northern bobwhite were translocated from Mexico. In 1932, translocation efforts were suspended and replaced by captive propagation efforts (Kentucky Game and Fish Commission 1975) that continued through 1989. Over that time span, an estimated 3.5 million northern bobwhite were released (Morgan and Robinson 2008). Pen-reared northern bobwhite release has repeatedly failed toward restoring populations throughout the last half century (Barbour 1950, Roseberry et al. 1987, Perez et al. 2002, Thackston et al. 2012).

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Despite the substantial efforts to mitigate waning northern bobwhite numbers in Kentucky, the population continued to decline. Breeding bird and rural mail carrier surveys in Kentucky demonstrated steady declines from 1960 to present with an annual rate of decline of 3% (Sauer et al. 2014, Morgan and Robinson 2015). Kentucky was joined by the majority of states across the northern bobwhite range with an annual range-wide decline rate of 4% from 1966 to 2012 (Sauer et al. 2014).

The focus on pen-reared release and captive propagation treated the symptom of widespread declines, not the cause. Clean agriculture, fescue-sod, plant succession, and development transformed Kentucky's landscape; the loss of widespread, connected habitat has been repeatedly identified as the root cause of the northern bobwhite decline (Brennan 1991, Guthery 1997, Burger 2002, Veech 2006, NBTC 2011). The Kentucky Department of Fish and Wildlife Resources (KDFWR) embraced that theme in 1986 with the establishment of one of the nation's first, state-funded habitat programs, the Habitat Improvement Program (HIP). During its inaugural 2 years, the program provided technical guidance to private landowners aimed at habitat improvement for declining small game populations (i.e., northern bobwhite, *Bonasa umbellus*, *Sylvilagus floridanus*). In 1989, HIP was funded with a $90,000 cost-share budget capped at $500 per landowner. Kentucky had charted a new course for recovering northern bobwhite.

Over the next 20 years, private lands biologists opportunistically worked with private landowners that invited them to their property (a reactive approach). HIP, US Forest Service (Forest Stewardship), and US Department of Agriculture (Farm Bill) conservation funding sources were deployed to cost-share enhancements. This conservation delivery strategy fostered widespread and piecemeal habitat enhancements, because Kentucky is over 90% private ownership (Wethington et al. 2003) with a 66 ha average farm size (U.S. Department of Commerce 2009). Field biologists anecdotally reported farm-based northern bobwhite responses to habitat management; however, state-wide survey data still demonstrated the continued declines. As the year's progressed, anecdotal reports curbed and sportsmen questioned that habitat was the primary problem.

The 21st Century brought new thinking to northern bobwhite conservation. The Bobwhite Quail Initiative (BQI) (Thackston et al. 2006) and the Coordinated Upland habitat Restoration and Enhancement Program (CURE) (Howell et al. 2002) were novel northern bobwhite programs established in Georgia and North Carolina, respectively. Both programs focused habitat efforts at multi-county levels with additional manpower and funding. They also monitored bird response and landowner attitudes. The programs were demonstrating positive northern bobwhite responses on many areas and informed agencies how to modify activities in circumstances where northern bobwhite did not respond (Thackston et al. 2006, Mark Jones, personal communication).

Soon after, the Northern Bobwhite Conservation Initiative (NBCI) (Dimmick et al. 2002) was released. A national vision for northern bobwhite restoration was established for 22 states. The goals for habitat and birds were defined at the Bird Conservation Region (BCR) level, and states were challenged to "step-down" those goals through state-based initiatives. The Missouri Department of Conservation (MDC) was the first state to create a strategic approach to deliver the NBCI to the ground and established county-based habitat targets (Missouri Department of Conservation 2003).

The culmination of a range-wide plan and state-based northern bobwhite restoration activity prompted KDFWR to aggressively pursue its own initiative. Contrary to MDC, we took a different approach for stepping down the NBCI in Kentucky. We lacked the manpower and funding to reasonably deliver state-wide conservation on the ground, and most notably, we lacked the knowledge of northern bobwhite response to habitat management at multiple scales (i.e., farm, focus area, and landscape) to confidently subdivide habitat targets across counties. Therefore, we created a strategic plan (a proactive approach) centered upon proving northern bobwhite could be restored at the focus area level (sub-county) with targeted habitat restoration and maintenance (Morgan and Robinson 2008). Herein, we present the results of focus area monitoring from 5 Kentucky focus areas from 2008 to 2013.

## STUDY AREA

Five areas were identified as focal area projects within Kentucky. The focal areas had variable sizes, land cover compositions, and landscape contexts (Table 1). All were located between 37°-38° N latitude and 84°-89° W longitude (Figure 1). Climate is Humid Subtropical characterized by relatively long, hot summers and short, mild winters with brief episodes of severe cold. Four of the areas (Shaker Village, Bluegrass Army Depot, Hart County CREP, and Livingston County) are within the Interior Plateau Level III ecoregion. Gently rolling hills with some areas of steep relief, karst topography, and deeply entrenched rivers are typical landforms for the Interior Plateau in Kentucky (Woods et. al. 2002). Peabody WMA falls in the Interior River Valleys and Hills Level III ecoregion. Uplands of moderate relief dissected by wide, poorly drained stream valleys are typical of this ecoregion (McDowell 1986). There is a long history of coal extraction including surface mining in this region. Forests in our study were typified by mature, closed canopy oak (*Quercus* spp.) and hickory (*Carya* spp.) with little understory vegetation and assumed to be poor northern bobwhite habitat. Peabody WMA forests were the exception, because eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and red maple (*Acer rubrum*) dominated overstories were open-canopied with developed understories (Brooke et al. 2015). Despite the enhanced value to northern bobwhite, they did not represent breeding habitat.

Focus areas were selected based on several criteria. The coarse aim was a mix of private and public land focal areas well distributed across the state. Finer selection

Table 1. The size (ha), ownership, and land cover composition (%) of northern bobwhite focus areas and surrounding landscapes (3000-m buffered area) in Kentucky from 2008-2013.

| | | | Developed | | Forest | | Open | | Water | |
|---|---|---|---|---|---|---|---|---|---|---|
| Area | Size | Owner | Focus | Landscape | Focus | Landscape | Focus | Landscape | Focus | Landscape |
| Blue Grass Army Depot | 5,875 | Public | 3.6 | 8.3 | 47.0 | 14.8 | 48.3 | 76.3 | 1.1 | 0.6 |
| Hart County | 8,024 | Private | 0.1 | 0.1 | 14.6 | 21.9 | 85.2 | 77.7 | 0.2 | 0.3 |
| Livingston County | 16,517 | Mixed | 0.0 | 0.6 | 46.6 | 36.1 | 47.3 | 42.7 | 6.0 | 20.5 |
| Peabody WMA | 8,847 | Public | 0.5 | 1.7 | 52.9 | 43.1 | 35.3 | 47.0 | 11.2 | 8.1 |
| Shaker Village | 1,160 | Private | 0.0 | 0.6 | 35.3 | 37.8 | 64.5 | 59.2 | 0.2 | 2.4 |

criteria included: existing northern bobwhite populations (based on KDFWR staff knowledge), specialized manpower, land use type, opportunity for management, area size, and landowner/manager interest. Efforts were also made to avoid, to the extent possible, areas that had a history of pen-reared northern bobwhite release. Landscape context was considered through comparisons to Kentucky's county prioritization model (Morgan and Robinson 2008, Morgan et al. 2012).

## METHODS

### Habitat and Harvest Management

Wildlife biologists leading focal area management activities strived to maximize annual disturbance. The activities were centered on open lands management. Disturbance rotations were targeted for a 2-year return interval, but those goals were not always met. Weather was the largest contributor to mis-timed return intervals. Primary management practices included prescribed burning, disking, herbicide applications (targeting invasive species primarily), and plantings (native grass establishment and rotational food plots). Total and unique management acres were tracked annually from 2009-13 for each focal area (Table 2). Management activities were spatially noted across the study period, but they were not collected annually. Activities were ongoing prior to the project, but management intensity and scale was dramatically increased beginning in 2009. Hart County was the exception with massive habitat establishment in 2007 and 2008.

Hunting was controlled to the extent possible within the focus areas. Peabody WMA was changed from a statewide hunting season framework (approximately 92 days in west zone) with unlimited numbers of hunters to highly controlled quota hunts with 6 hunting days and 6 parties (maximum of 3 hunters per party) per day. Bluegrass Army Depot was closed to northern bobwhite hunting throughout the study. Livingston County and Shaker Village Focus Areas, were each hunted at conservative levels through guidance provided by KDFWR biologists. No specific hunting data was collected, but annual personal communications were

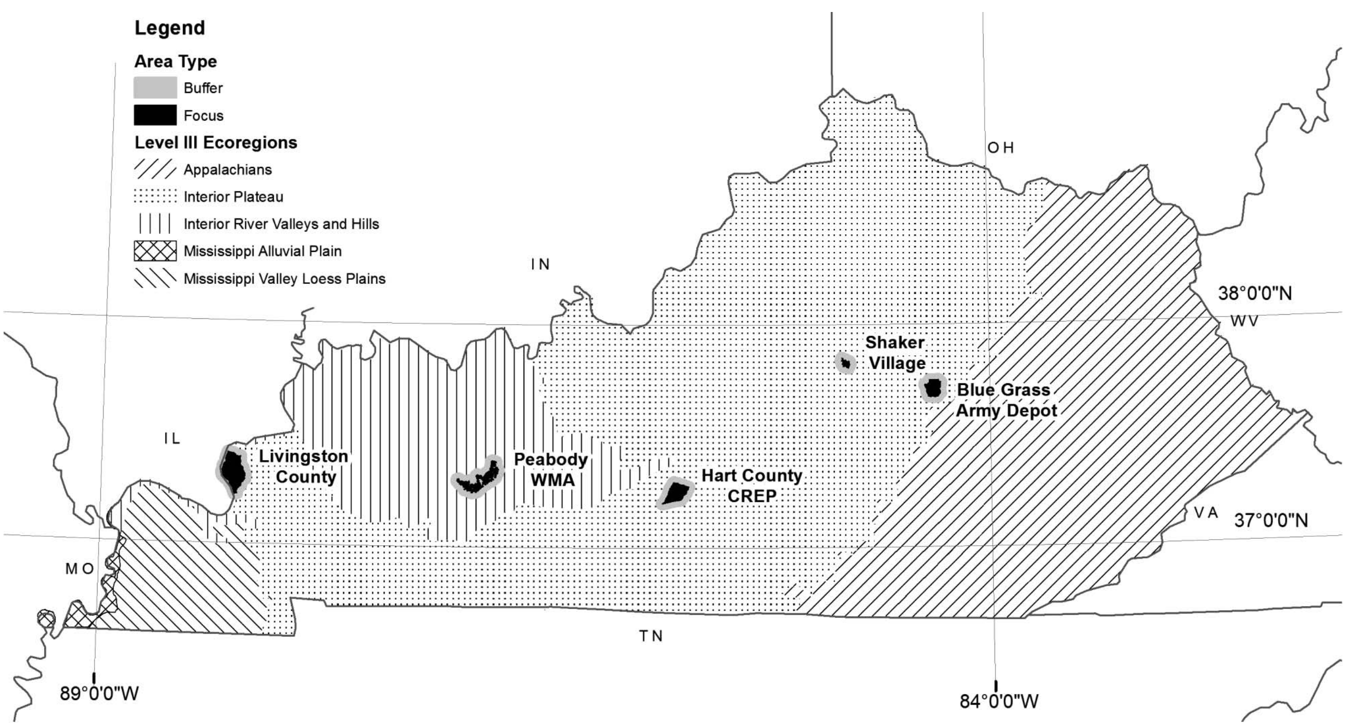


Fig. 1. The location, landscape buffer (3,000 m), and ecoregion of five, northern bobwhite focus areas in Kentucky, 2008-13.

Table 2. The total management practices implemented (ha) in northern bobwhite focus areas in Kentucky, 2009-2013.

| | Focus Area | | | | |
|---|---|---|---|---|---|
| Practices | Blue Grass Army Depot | Hart County | Livingston County | Peabody WMA | Shaker Village |
| Controlled Burning | 1,554 | 0 | 1,399 | 729 | 547 |
| Disking | 6 | 87 | 63 | 450 | 0 |
| Herbicide Application | 95 | 140 | 372 | 160 | 576 |
| Planting[a] | 85 | 1,203[b] | 616 | 45 | 227 |
| Grazing | 1,119 | 0 | 0 | 0 | 0 |
| Woody Control | 15 | 0 | 834 | 0 | 0 |
| Total Unique Units[c] | 531 (9) | 1,203 (15) | 1,660 (10) | 845 (10) | 418 (36) |

[a] Includes planting of prairie restoration, fire break cover crops, and rotational, annual grain food plots.
[b] Practices completed in 2007 and 2008.
[c] Management practices were often repeated on the same hectare within a year and across years. The total eliminates double counting of hectares within and across years. Parenthesis represent proportion (%) of the focus area managed across the study period.

maintained. The Hart County Focus Area was available to state-wide hunting seasons (90 days in east zone) with no specific guidance from KDFWR biologists on hunt pressure.

## Bird Monitoring

Bird monitoring was designed to measure northern bobwhite density across the focus area. We assumed northern bobwhite could be detected out to 500 m (Wellendorf and Palmer 2005), so we developed a 2000-m grid system for the entire state with ArcGIS. Two thousand meter grid cells provided a 500-m buffer around each point to maximize spatially independent monitoring points in each focal area. National Land Cover Data (NLCD, Fry et al. 2011) was reclassified into four classifications: open, forest, water, and developed to identify potential northern bobwhite habitat (hereafter, referred to as "open"). Each polygon was set to a minimum of 10 ha in size, because it was assumed the patch would represent the minimum suitable size a whistling male northern bobwhite would utilize.

Using ArcGIS, the statewide grid system was intersected with the focus area boundaries. A centroid point was placed in each grid cell as the initial starting point for a systematically random point selection process. Centroids located outside the focus area boundary were excluded from sampling. A single analyst at a 1:10,000 extent examined the national landcover dataset with respect to each centroid. Point selection started at the northernmost cell and systematically moved southward by rows.

We used the landcover dataset and Farm Services Agency (FSA, U.S. Department of Agriculture 2010) aerial imagery to conduct the point selection process. Transparency was set at 80% for the landcover dataset to allow simultaneous viewing of imagery to verify model accuracy when selecting points. Model misclassifications were corrected during the point selection process. For example, if a forest land cover was classified as "open" in the NLCD, but the imagery clearly showed forest, then observers interpreted it as "forest". The FSA aerial imagery was assumed to be 100% accurate.

The goal of point selection was to place the sampling point in the perceived center of the first open patch (bobwhite breeding habitat) within the 2000-m grid cell. If the centroid was in an open patch, the observer selected a point in the perceived center of that open patch within that 2,000 m grid cell. If the centroid was not in an open patch, then the observer looked due north and moved clockwise until intersecting an open patch. Should two independent patches (i.e., not connected as some point within the 2,000 m grid cell) exist along the same bearing, then the closest patch to the centroid was selected. Again, the observer placed the sampling point within the perceived center of the open polygon with respect to the 2,000 m grid cell. If no open polygons were intersected, then the point was placed in the perceived center of the patch identified by the centroid.

Standard breeding bird point counts were used by a single observer over a 5 minute monitoring period. Observers recorded calling locations of northern bobwhite and a suite of grassland songbirds on paper datasheets containing aerial images with superimposed distance bands (50,100, 250, and 500 m). Two aerial images were on utilized on each datasheet. A zoomed 100 m image (1:1,500 scale) was adjacent to a map encompassing the 500 m sampling area. Observers recorded birds that were within a 100 m on the zoomed map and birds beyond 100 m were recorded on the full extent map (1:6,000 scale). Time of first detection was noted next to the appropriate American Ornithological Union species code. Bird movements were tracked by the use of arrows on the datasheet during the sample period. If multiple observers supported a focus area, their sample points were spatially distributed across the area. The same observers were used across the study period. Up to three repetitions were completed each year (first 2 weeks of June, second 2 weeks of June, and first 2 weeks of July). Monitoring routes were reversed between repetitions.

## Landscape and Weather Metrics

We used ArcGIS to assess landscape composition within and outside each focal area. The landscape was defined as a 3,000 m buffer around the focal area boundary (Twedt et al. 2007). NLCD 2011 values were reclassified to forest, open, water, and development land cover types and tabulated as a percentage within focus areas and the surrounding buffers. We used spatially-explicit shape file data from FSA to assess Conservation Reserve Program (CRP) contract acres for each year of the study. Those acres were also converted to a percent at the focus area and surrounding landscape. For assessing the variability among focal areas, we digitized management units across focal areas to calculate mean and standard deviation of compactness (a measure of shape in relation to edge), size of management units, number of management units, and average distance between management units (m).

We compiled summer breeding season and late winter weather data. We independently summed (no breeding season had positive and negative scores in a single season) positive and negative weekly Palmer Drought Index scores (National Oceanic and Aeronautical Administration 2016) from June through August to establish a wet and drought breeding season metric, respectively. For late winter weather, we used the closest weather station and counted the number of days below -5 degrees Celsius (Robel and Kemp 1997) in a calendar month from December through February each year.

## Statistical Analyses

We used a model with two main components to estimate northern bobwhite population parameters: 1) a hierarchical distance sampling model to estimate detection probabilities and densities of northern bobwhite (Royle et al. 2004, Sollmann et al. 2015), and 2) a growth model to estimate density-independent and density–dependent population growth (Dail and Madsen 2011, Hostetler and Chandler 2015, Ricker 1954). We estimated three population parameters: abundance in the initial year of sampling ($\alpha$), density-independent growth rate ($\theta_0$), and regulation of growth rate by population density ($\theta_1$). We modeled focus-area-level estimates for $\alpha$ and $\theta_0$ as random variables drawn from a hierarchical (i.e., region-wide) distribution. The hierarchical distribution described what we could expect initial abundance and density-independent growth to be if other focus areas were established in our study region, thus broadening our inference. We used a negative binomial distribution to account for dispersion of counts in the initial year of sampling for each sampling location $i$:

$$N_{i,1} \sim \text{Negative Binomial}(P, r)$$

$$P = r / \left( r + \exp(\alpha\left[\text{focus}_f\right]) \right)$$

$$\alpha\left[\text{focus}_f\right] \sim \text{Normal}(\mu_\alpha, \sigma_\alpha)$$

where $P$ describes the number of successes (i.e., abundance), $r$ describes dispersion, and $\alpha[\text{focus}_f]$ describes expected abundance on the log scale differing by focus area $f$ which were random draws from a normal distribution with mean $\mu_\alpha$ and variance $\sigma_\alpha$.

We used a Poisson distribution to describe abundance in subsequent years $t$=[2…6]:

$$N_{i,t} \sim \text{Poisson}\left( N_{i,t-1} \cdot \exp(\theta_0\left[\text{focus}_f\right] + \theta_1 N_{i,t-1}) \right)$$

$$\theta_0\left[\text{focus}_f\right] \sim \text{Normal}(\mu_{\theta 0}, \sigma_{\theta 0})$$

where $N_{i,t}$ describes abundance at site $i$ for year $t$, $\theta_0[\text{focus}_f]$ describes density-independent growth at each focus area which were random draws from a normal distribution with mean $\mu_{\theta 0}$ and variance $\sigma_{\theta 0}$, and $\theta_1$ describes the strength of regulation of growth by population density. Regulation of growth by population density was assumed to be constant among focus areas.

We modeled observations ($y$) as a two-stage process. We estimated detection probability $p$ using distance sampling information. Frequencies of observations in each of our distance classes were modeled as a multinomial process:

$$ty_i, \text{t} \sim \text{Binomial}(N_{i,t}, pCirc_t)$$

$$ydet_{i,1:nB,t} \sim \text{Multinomial}(y_i, \text{t}, pi_{1:nB,t})$$

where $y_{i,t}$ describes the number of males detected for site $i$ in year $t$, $pCirc$ is the overall detection probability within a point count in year $t$, $ydet$ describes the number of birds observed in each of our 5 distance bins (nB) at each site each year, and $pi$ describes normalized detection rate for each distance bin.

For each distance bin $b$ we modeled detection $p$ as a half-normal function with a tuning parameter $\sigma$ that varied by year:

$$p_{b,t} = \frac{\left( \sigma_t^2 \frac{1-\exp(-db[b+1]^2)}{2\sigma_t^2} \right) \times \left( \sigma_t^2 \frac{1-\exp(-db[b]^2)}{2\sigma_t^2} \right) \times 2\pi}{pa \times pix[b]}$$

$$pi_{b,t} = p_{b,t} \times pix[b]$$

where $db$ is the boundary of each distance bin, $pa$ is the area of a point count, and $pix$ is the proportion of the sampling point area encompassed by each distance band. We then calculated $pCirc$ as $\Sigma pi_{1:nB,t}$. We analyzed the model in a Bayesian framework using three independent Markov Chain Monte Carlo (MCMC) simulations. We adapted the MCMC algorithm for 1,000 iterations then ran the model for 100,000 iterations and used visual interpretation of trace plots to determine model convergence. We calculated Pearson's residuals for each estimate of N in each year to determine model fit. We summarized results after discarding the adaptive phase and 50,000 iterations per chain.

The sample size of focus areas (n=5) and scale of information (i.e., focus-area-specific information only) precluded the inclusion of covariates in modeling efforts, so we conducted a Principal Components Analysis (PCA) as an informal way to evaluate variation of local, landscape (3,000 m), and weather variables among northern bobwhite focus areas (Table 3; PRIMER 5.2.9; Primer-E Ltd, Roborough, Plymouth, United Kingdom).

Table 3. Description of focus area variables included in Principle Components Analysis (PCA) of northern bobwhite focus areas in Kentucky, 2008-2013.

| Variable | Description |
|---|---|
| year | year of data collection |
| size | focus area size (ha) |
| perforfoc | % forest composition within focus area |
| perforlan | % forest composition in landscape around focus area |
| peropnfoc | % open composition within focus area |
| peropnlan | % open composition in landscape around focus area |
| perwatfoc | % water composition within focus area |
| perwatlan | % water composition in landscape around focus area |
| perdevfoc | % developed composition within focus area |
| perdevlan | % developed composition in landscape around focus area |
| percrpfoc | % CRP composition within focus area |
| percrplan | % CRP composition in landscape around focus area |
| wet | sum of + weekly Palmer Drought Index scores(breeding[a]) |
| drought | sum of – weekly Palmer Drought Index scores (breeding[a]) |
| winter | count of days ≤ -5° C (December – January) |
| perinmgt | % of unique acres managed within focus area |
| fields | # of management unit within focus area |
| meanmgt | mean hectares of management units within focus area |
| meancom | mean compaction of management units within focus area |
| sdcom | SD compaction of management units within focus area |
| distmgt | mean distance (m) between management units |

[a] Breeding season was June through August.

# RESULTS

We sampled 40, 104, 104, 113, 106, and 63 sites from 2008 to 2013 and detected 0.450, 1.115, 1.202, 1.646, 1.415, and 1.825 singing male northern bobwhite per point, respectively. Detection probabilities from 2008 to 2013 were 0.124 (0.086—0.173 95% Bayesian Credible Intervals [BCI]), 0.238 (0.201—0.280 95% BCI), 0.249 (0.214 —0.286 95% BCI), 0.265 (0.230 —0.305 95% BCI), 0.253 (0.216—0.294 95% BCI), and 0.301 (0.247—0.365 95% BCI), respectively.

Our model predicted hierarchical mean density in 2008 to be approximately 16.5 ha/singing male (10.1—30.6 95% BCI) ($\mu_\alpha = 1.301$, 0.731— 1.837 95% BCI; $\sigma_\alpha = 0.440$, 0.058—1.358 95% BCI). Estimates of mean density across focus areas ranged from 12.99—21.28 ha/singing male in 2008 to 7.04—9.43 ha/singing male in 2013. According to model estimates, there is a 0.992 probability that populations were growing (i.e., $\mu_{\theta 0}$ was positive) in our focal areas during this study and our model estimated hierarchical density-independent growth to be 35.7% annually ($\mu_{\theta 0}$=0.305, 0.114—0.498 95% BCI; $\sigma_{\theta 0}$=0.092, 0.004—0.310 95% BCI). The probability that populations were growing at each focal area was at least 0.996 and mean annual density-independent growth ranged from 28.1—40.5% across focus areas (Table 4, Figure 2). Regulation of growth rates by density was 3% and did not markedly affect population size over time (Figure 2; $\theta_1$=-0.030, -0.051—-0.012 95% BCI).

Differences among focal areas were mostly defined by land composition. PCA resulted in 93.2% of variation among focal areas being explained by the first three axes. The variables dominating the first axis were land composition variables at the focus (perforfoc, peropnfoc) and landscape (perforlan, peropnlan) scales with the exception of drought. Axis two included more land composition metrics (perdevfoc, perdevlan), percrpfoc, winter, and SD compact. The third axis brought in important spatial metrics such as perinmgt, distmgt, and meanmgt.

# DISCUSSION

Our focus areas successfully grew breeding populations of northern bobwhite over a 6-year period, and they lend strong support for the landscape-level habitat paradigm for restoration (Williams et al. 2004, Hernández et al. 2013). The Department's own history and experience reinforced the need to work beyond the local (farm) scale. Our areas exhibited a mean annual growth rate of 35.7% that directly contrasted with the 3% annual decline from Breeding Bird Survey data over a similar period (Sauer et al. 2014).

Few studies have demonstrated favorable responses to purposeful management at larger management scales (Brennan 2012). Our work represents one of the pioneering projects linking managed northern bobwhite habitat to population growth at the subcounty level. As such, it satisfied the primary goal established in KY's northern bobwhite restoration plan. Across the study period, the proportion of the areas managed for improved habitat ranged from 9 to 36%. If KDFWR was to establish a new focus area, then the probability of growing the

Table 4. Northern bobwhite (Colinus virginianus) mean population growth rate (log-scale, density independent) at each focus area in Kentucky, 2008-13

| Focus Area | Growth rate | Lower 95% BCI | Upper 95% BCI | Probability of positive growth |
|---|---|---|---|---|
| Blue Grass Army Depot | 0.325 | 0.142 | 0.513 | 0.998 |
| Hart County CREP | 0.340 | 0.166 | 0.519 | 0.998 |
| Livingston County | 0.328 | 0.132 | 0.535 | 0.998 |
| Peabody WMA | 0.247 | 0.057 | 0.427 | 0.986 |
| Shaker Village | 0.287 | 0.099 | 0.469 | 0.986 |

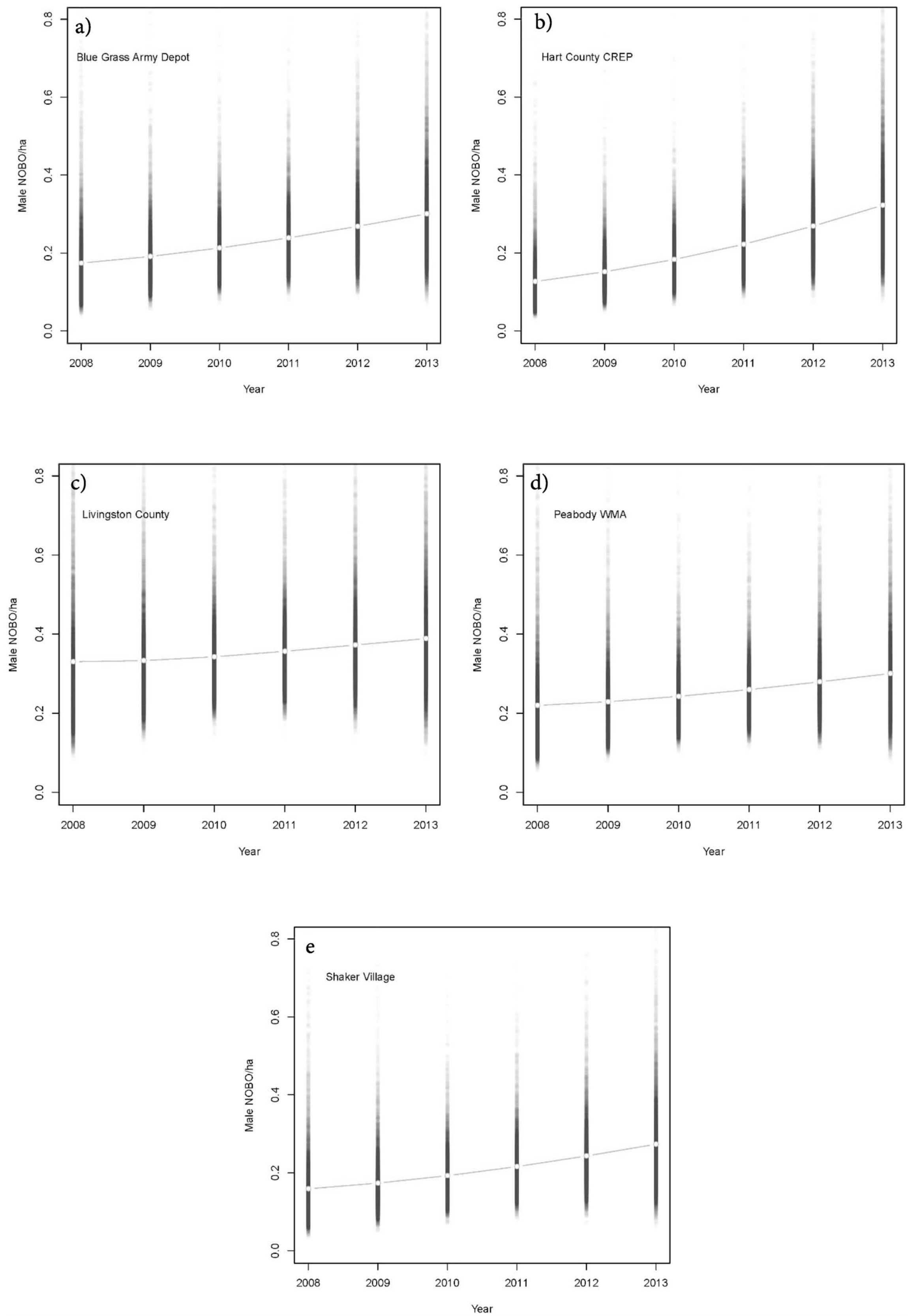


Fig. 2. The mean density and 95% BCI of breeding male northern bobwhite in five focus areas in Kentucky from 2008 to 2013.

population following similar guidelines is 99%. These results clearly demonstrated that we can successfully grow northern bobwhite breeding populations with a commitment to establishing and maintaining habitat. KDFWR has a powerful platform to share with the state's landowners that have an interest in northern bobwhite.

An understanding of what characterized our focus areas provides critical guidance for the future. Areas were in agricultural or non-forest dominated landscapes aligning with Riddle et al.'s (2008) recommendations. Peabody WMA was an exception (53% forested), but it was a reclaimed mineland site. The area's forest classification is not typical of prevailing forest cover (mature, closed-canopy hardwoods) and is characterized by open hardwood canopies with thick understories (Brooke et al. 2015). Despite the similarity in landscape composition at the coarse-scale, PCA results demonstrated that variability among our areas was largely explained by land cover composition within and outside the focus areas. Peabody forest composition may have confounded that analysis, but our results suggest that in non-forested landscapes, an array of land compositions can grow northern bobwhite breeding populations. Roseberry and Sudkamp (1998) modeled habitat suitability favoring 75 to 90% open lands. Open areas (row crops and grassland land cover) ranged from 35 to 85% in our focus areas, so we were successful growing northern bobwhite in more marginal environments. What appeared more important to northern bobwhite growth were the habitat management actions themselves. Management explained little of variation among the focus areas in our PCA. Hence, habitat management consistently produced northern bobwhite population growth across all our areas.

Twedt et al. (2007) noted targeting 5,000 ha areas with >200 northern bobwhite in the population for restoration. It is difficult to directly compare our first-year density estimates to this recommendation because 1) Twedt et al. (2007) assumed perfect detection of singing males and a constant relationship (12*x*) between a single singing male and its subsequent covey size, 2) Twedt et al. (2007) used a suite of land cover variables to predict abundance across space, and 3) if we were to extrapolate our density estimates beyond our point counts, we would be assuming no spatial heterogeneity in density. However, our results suggest that radical changes in landscape composition (>10%) in short periods of time can jump start relatively low northern bobwhite densities in a variety of non-forested landscapes in Kentucky. Smaller areas can produce results if more dramatic habitat enhancements are completed. Shaker Village had substantial habitat enhancement (36%), but was only 1,160 ha.

Our analysis was limited by extreme variation among our focal areas and incomplete annual data. Areas were selected because of their unique attributes providing opportunities for northern bobwhite conservation. The diversity of prospects included mineland reclamation, Conservation Reserve Program land, Conservation Reserve Enhancement Program land, large-scale private lands prairie restorations, and a grazing operation. While diversity of management opportunities gives hope to the overall northern bobwhite restoration effort, it fosters a poor laboratory for study. Annual variability is a well-known attribute influencing northern bobwhite populations (Stoddard 1931, Roseberry and Klimstra 1984, Guthery 1997, Lusk et al. 2002). Our PCA analysis did highlight drought as an important variable explaining differences among our focus areas, so considering weather parameters should remain a core variable of future focal area assessment. With more powerful data, drought may have been able to explain variability within focal area northern bobwhite responses particularly when combined with habitat data (Webb and Guthery 1982, Rice et al. 1993). Our management actions were spatially accounted over the entire study period, but not for each individual year. That limited our ability to assess juxtaposition, relationship with weather, and an innumerable landscape metrics within the focus areas annually.

We agree with Williams et al. (2004) that harvest strategies should be implemented to avoid risking the primary goal of restoring northern bobwhite. We are confident that hunting was conservative across our study period. Public lands focus areas had controlled hunts that created low harvest rates (< 20%), and frequent communication with landowners in Livingston County and Shaker Village also fostered low harvest rates. Hart County was the only area that we lacked any knowledge of hunting activity. If hunting is not controlled in focus areas, then it is imperative that data be collected to measure its effect on northern bobwhite population growth.

## MANAGEMENT IMPLICATIONS

Purposeful management to grow northern bobwhite populations at the subcounty level has not been documented. A myriad of landowners, non-government organizations, universities, and government agencies have invested in efforts to restore northern bobwhite across the range. KY focus areas consistently grew northern bobwhite populations when radical changes (≥10% of the focus area) of new habitat were established and maintained. Small areas (approx. 1,000 ha) can be effective, but likely require more dramatic habitat enhancement. Selecting focus areas should take into account landscape composition (favoring agricultural, grassland, or non-closed canopy forested areas), offer significant opportunity for future management, and support existing populations of northern bobwhite (at least 44 ha/bird). Measures to control northern bobwhite harvest should be implemented, but if harvest is uncontrolled, standardized methods of collecting harvest information on public and private landscapes are an important need moving forward. Coordinated programs leveraging data across state lines foster powerful datasets to model the connection between landscape context, weather, management, harvest, and northern bobwhite density. It is imperative that management actions be spatially explicit (annually) to provide a full picture of how habitat management influences northern bobwhite population growth. Understanding the factors that drive northern bobwhite population growth in focus areas can inform future restoration efforts by minimizing risk and cost.

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