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ABSTRACT

Planning the management of northern bobwhite (*Colinus virginianus*) habitat at a statewide-scale is daunting. Native grassland restoration is difficult to manage in Kentucky because > 99% of the Commonwealth's original grassland area has been lost to agriculture, succession, and development. We created a county prioritization model designed to target areas of grasslands and landowners likely to participate in conservation programs. Our goal was to identify 10% of the state as high priority for bobwhite habitat restoration. We created an east and west model divided by the Appalachian Mountains. The west model was designed to target production-oriented operators farming marginal lands, whereas the east model targeted reclaimed minelands. We used agricultural, landcover, and staff data to build county prioritization models in 2006 and 2011. The models targeted 16.6% and 17.6% of the state in 2006 and 2011, respectively. However, if areas of large, contiguous blocks of forests were excluded, the area total was much closer to 10%. Fifty percent of the high priority counties changed in the west model, and 33% of the counties in the east model changed over 5 years. Implementing a county prioritization model in conjunction with a finer-scale, biological targeted approach could focus conservation efforts with greater potential for success, but the models should be reconstructed at 5- to 10-year intervals to account for changes in conservation delivery potential. A modification of our technique may serve to validate or as an alternative to improve National Bobwhite Conservation Initiative 2.0.

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Key words: *Colinus virginianus*, delivery, grasslands, habitat, Kentucky, model, northern bobwhite, prioritization, restoration, target

INTRODUCTION

The northern bobwhite was once a prominent component of the rural landscape in Kentucky. Widespread changes in land management, agriculture, and development decimated native grasslands and decreased wild bobwhite populations over the course of half a century (Morgan and Robinson 2008). Bobwhites had declined by ~ 83% between 1968 and 2010 (NBCI 2011). The Northern Bobwhite Conservation Initiative (NBCI) was developed by 2002 and generated a call to action for stopping the decline and restoring the species to the population levels of 1980 (Dimmick et al. 2002).

The plan was designed as an umbrella, providing a single vision for range-wide bobwhite restoration. Member states agreed to 'step-down' NBCI goals to local levels using Bird Conservation Regions within their jurisdictions (Dimmick et al. 2002). Delivering state-wide conservation for bobwhite in Kentucky was impractical and infeasible with limited funding and personnel. We faced the challenge of prioritizing management efforts across the state to generate a positive bobwhite population response with the least amount of effort (money and personnel) and the highest potential for success.

Researchers and biologists have developed techniques to improve conservation across broad landscapes (Johnson et al. 2004; Twedt et al. 2006, 2007). However, the focus has been on biological parameters and fail to include social and economic considerations which are critical for conservation delivery potential. We aspired to build a model that incorporated biological and conservation delivery components designed to ensure bobwhite restoration occurred on the ground. This model would function as an operational program for bobwhite restoration in Kentucky (Knight et al. 2006).

We created a mechanism to use available spatial data, bobwhite population data, and expertise of field personnel on private lands to build a county prioritization model for

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bobwhite habitat development. The county level was selected because it is widely understood among the public, it served as a base unit for conservation delivery (e.g., state and federal personnel are assigned to counties), and there were many data sets at that scale. The goal was to identify a maximum of 10% of the state's area as high potential for bobwhite restoration over a 10-year period.

STUDY AREA

The Commonwealth of Kentucky ranks 26th nationally in terms of population (4,314,113 people) which increased 6.7% from 2000 to 2009 (USDC 2009a). Historically a rural state, 44% of the population now lives in an urban area (USDC 2004). There are 120 counties that function as important political and social units. Private landowners hold ~90% of the land base (Wethington et al. 2003). Agriculture remains a vital part of the economy employing nearly 113,000 workers (Kentucky State Data Center 2005) with 86,000 farms, 56,656 km^2 in production, and average farm size of 66 ha (USDC 2009b). Extensive coal fields in eastern and west-central Kentucky are also important to the state's economy.

All of Kentucky is within the Köppen climatic classification of Humid Subtropical characterized by relatively long, hot summers and short, mild winters with brief episodes of severe cold (McKnight 1990). A moderate north-south precipitation gradient exists with southern counties receiving slightly more (127 cm) annual precipitation while northern counties receive less (114 cm) (Prism Climate Group 2006). Forest covered much of Kentucky at the time of European settlement with extensive grasslands and wetlands present in the western portions of the state. Satellite imagery reveals that about 50% of Kentucky remains forested while most grasslands and wetlands have been converted to agriculture (Kentucky Division of Geographic Information 2007c).

A distinct east-west elevation gradient heavily influences natural vegetation, as well as human settlement and land use patterns. The eastern one-third of Kentucky is within the Level II Ozark ecoregion, Ouachita-Appalachian Forests or Appalachian Plateau (Commission for Environmental Cooperation 1997). Elevation is generally below 900 m with few exceptions. The topography throughout this region is extremely steep and rugged with shallow soils limiting potential for agriculture. Surface mining, including mountain top removal, has left large, relatively flat, open areas where none existed previously.

Central and west-central Kentucky are within the Level II Southeastern USA Plains ecoregion or Interior Low Plateau (Commission for Environmental Cooperation 1997). The topography is less rugged and soils are more conducive for agriculture. However, steep hillsides are common and their use is primarily marginal pasture land. Extreme western Kentucky contains the Mississippi Alluvial Plains and Southeast USA Coastal Plains Level II ecoregions (Commission for Environmental Cooperation 1997). This area is relatively low and flat sharing many aspects with more southern coastal plain states. Soils are generally deep and highly fertile allowing for intensive row crop agriculture.

METHODS

We divided Kentucky into eastern and western zones to account for major differences in landcover, topography, and agriculture. The east-west dividing line roughly follows the Level II Appalachian Plateau ecoregion. County lines were used to define the boundary rather than purely physiographic ecoregions to allow use of county level statistics. Bordering counties were assigned based upon the percent within east or west zones. The eastern Kentucky zone included 32 counties (29,265 km^2, 28% of the state) while the western Kentucky zone included 88 counties (75,385 km^2, 72% of the state).

Data were selected to target counties with relatively high existing northern bobwhite populations, high potential to support bobwhite habitat, predominately production farms on marginally productive soil or reclaimed minelands, potential to deliver conservation objectives, and potential to benefit other species. The variables analyzed differed between the west (Table 1) and east (Table 2) zones. We assembled the most recent data available in 2006 and in 2011.

Bobwhite populations were indexed through the Mail Carrier Survey, a Kentucky Department of Fish and Wildlife Resources (KDFWR) data set containing reports from rural mail carriers of bobwhite road-side observations relative to kilometers driven. We quantified potential quail habitat in the west zone using county enrollment (total ha) in Conservation Reserve Program (CRP) while the National Landcover Database (NLCD) (Kentucky Division of Geographic Information, 2007b, c) was used in the east. Counties with high enrollment were targeted for the west region and counties with large areas of open habitat were targets for the east. Production farmers with marginal soils were assumed to better realize the economic benefits of agricultural retirement and buffer or field border programs. A Corn Index was developed to focus on marginal soils, and counties with low production were assumed to have more marginal soils (USDA 2002).

We approached delivery of conservation objectives (potential for future management) through several data sets. KDFWR public access agreements with large landowners (primarily reclaimed mine land) represent the best opportunity to enhance significant open habitat areas in the east zone. County rating and USDA rating data sets were created by polling KDFWR private lands biologists and farm bill biologists across the state (Morgan and Robinson 2008). Each survey participant provided a qualitative county rating that was converted to a numerical value (3, 2, and 1) with high scores representing preferred counties. Scores were averaged when multiple biologists provided surveys for the same county. Statewide Overlapping Conservation Areas from the Kentucky State Wildlife Action Plan (SWAP) provided information about potential benefit to other species (KDFWR 2010).

Table 1. Description, target, and county-level data sources for the 2006 and 2011 northern bobwhite county prioritization model in western Kentucky.

Variable	Description	Target	2006 Data source	2011 Data source
CRP[a]	Total area[b] (double weighted)	Existing grass; delivery	2006 USDA[c] data	2010 USDA data
Corn Index	Corn planted for all purposes as yield per ha[d]	Marginal soil	2006 Corn data	$\bar{x}$ from 2001–2010
Farmers	% of farmers as principle operator	Production farmers	1997 Farm statistics	2007 Farm statistics
USDA rating	KDFWR[e] field staff rating of USDA county's effectiveness and wildlife interest	Delivery	2006 Staff	2006 Staff
NRCS[f] office	Presence or absence of a NRCS service center	Delivery	2006 Staff	2006 Staff
Mail Carrier	Bobwhite mail carrier survey	Bobwhite presence	Mean from 2001–2006	Mean from 2007–2011
County rating	KDFWR field staff rating on county's overall potential for bobwhite restoration	Delivery	2006 Staff	2011 Staff
SWAP[g]	Intersection of SWAP priority areas and county layers; taking highest priority level	Multi-species benefit; funding	2005 SWAP priority areas	2005 SWAP priority areas

[a] Conservation Reserve Program.
[b] Included Conservation Practices 1, 2, 25, and 33 in 2006 and Conservation Practices 1, 2, 10, 22 (in Conservation Reserve Enhancement Program counties only), 25, 29, 33, and 38 in 2011.
[c] U. S. Department of Agriculture.
[d] Corrected for extent by multiplying by thousands of hectares planted.
[e] Kentucky Department of Fish and Wildlife Resources.
[f] Natural Resources Conservation Service.
[g] State Wildlife Action Plan.

Data management was performed using MS Access (Microsoft, Redmond, WA, USA) with ArcMAP (ESRI, Redlands, CA, USA) serving to spatially integrate data sources and produce maps. Access 2003 and ArcMAP 9.3 were used to process data in 2006, and Access 2007 and ArcMAP 10.0 were available in 2011. These software upgrades posed no problems for data analysis.

Kentucky county polygons were used as the minimum mapping unit (Kentucky Division of Geographic Information 2007a). Most data sources existed as county level tables, but some required manipulation. ArcMAP was used to intersect county polygons with NLCD landcover types, SWAP priority areas, KDFWR access agreement areas, and extract tables that were imported into Access.

The general process for generating county values for analysis involved ranking each county variable, summing those ranks, and ranking the summed scores again. County tables were loaded into ArcMAP, divided into 5 classes, and assigned scores of 1–5 using the Jenks Natural Breaks method (Jenks 1967). Each variable score was summed for each county generating a summed score.

Table 2. Description, target, and county-level data sources for the 2006 and 2011 northern bobwhite county prioritization model in eastern Kentucky.

Variable	Description	Target	2006 Data source	2011 Data source
Grass and shrub	Sum (%) of grass and shrub landcover; (double weighted)	Existing grass	2001 NLCD[a]	2005 NLCD
Barren	% barren landcover	Existing grass	2001 NLCD	2005 NLCD
Access	KDFWR[b] access agreements on reclaimed mine areas	Delivery	2006 Public hunting boundary	2011 Public hunting boundary
Mail Carrier	Bobwhite mail carrier survey	Bobwhite presence	Mean from 2001–2006	Mean from 2007–2011
County rating	KDFWR field staff rating on county's overall potential for bobwhite restoration	Delivery	2006 Staff	2011 Staff
SWAP[c]	Intersection of SWAP priority areas and county layers; taking the highest priority level	Multi-species benefit; funding	2005 SWAP priority areas	2005 SWAP priority areas

[a]National Landcover Data.
[b]Kentucky Department of Fish and Wildlife Resources.
[c]State Wildlife Action Plan.

The CRP score was double weighted for the western region as was the summed proportions of barren, grass, and shrubs in the east region. Summed county scores were converted to a 1–4 rank (High, Medium, Low, and Very Low) following Jenks (1967). We used 4 categories to meet the 10% statewide area goal.

This methodology was applied separately to the eastern and western zones. West zone scores were assigned to all 120 counties, while east zone scores were limited to the 32 counties comprising that zone. We investigated both within year variability and change between years. Within year variable independence was tested with Spearman's rank correlation and Pearson Product Moment Correlation. Principle Component Analysis (PCA) was used to examine the within year drivers of county prioritization in the model.

We analyzed how county priority scores changed between 2006 and 2011 in response to updated data (Tables 1, 2). Only SWAP priority areas data did not change. New county level tables were generated and the process was repeated. We examined the correlation between 2006 and 2011 for county rating and USDA rating to investigate the effect of varying KDFWR staff. ArcMAP was used to identify and visually depict changes in county priority between years.

RESULTS

The models performed well for prioritizing bobwhite conservation in Kentucky. The 2006 model identified 15 high priority counties across the state totaling 1,648,737 ha (1,440,274 west, 208,463 east), whereas the 2011 model had 15 high priority counties totaling 2,248,320 ha (1,506,917 west, 741,403 east) (Figs. 1, 2). Fifty percent of the high priority counties changed in the west and 33% in the east between the 2006 and 2011 models.

The models yielded 16.6% and 17.6% of the state in the high priority category from 2006 and 2011, respectively. Eliminating large, forested tracts within high priority counties would have resulted in being closer to our 10% target (12.7% in 2006 and 13.6% in 2011). Our procedure emphasized the western zone (83% of the high priority counties) where the greatest potential for bobwhite restoration exists.

The western model could have been simplified and yielded similar results. Fourteen of the 28 paired comparisons were correlated ($P < 0.05$) making the model not highly orthogonal. The first 3 axes of the PCA for the 2006 west model explained 64% of its variability. The driving variables were the SWAP priority areas (axis 1), the USDA staff rating (axis 2), and the percent of farmers as principle operators (axis 3). Sixty-four percent of the variation in 2011 was also captured by the first 3 axes, but they were mail carrier, USDA score, and Natural Resources Conservation Service (NRCS) office, respectively. The Corn Index and staff county rating added little prioritization value to the model. Presence or absence of CRP likely was representative of soil quality across the county and had a large role in a staff member's county rating. Staff county rating and USDA rating were highly inter-related, and using only one would be appropriate.

The eastern model was more parsimonious and yielded a reasonable product. Only 3 of 15 variable combinations had significant correlations ($P < 0.05$), and the PCA of the 3 primary axes accounted for 70% of the model variation in 2006. Grass and shrub score, SWAP priority areas, and staff county rating were the factors with highest loadings on the first, second, and third axis, respectively. The same three variables at each axis in 2011 accounted for 75% of the variability.

Data currency and quality were a problem in our models. Staff changes resulted in potential inconsistencies among survey parameters. The rating a county received by staff in 2006 and 2011 was correlated ($P < 0.001$) with staff change. However, USDA staff county ratings between years were not correlated ($P > 0.05$) despite staff change.

The 2006 west model relied upon on-line Farm Service Agency (FSA) data for CRP enrollment. We believed it was one of least reliable metrics regarding data quality, yet the most important to target. We dramatically improved data quality in the 2011 western model by working directly with Kentucky-based FSA staff. The 2011 model was superior, because of the higher quality CRP data set.

The eastern model targeted scrub-shrub, barren, and grassland landcovers for prioritization. The most current landcover data in 2006 was from 2001. Mining activity in eastern Kentucky is far from static, and many areas had changed since initial classification. The 2011 model exhibited the same shortcoming, but the data were from 2005. KDFWR access agreements in the model presented an ever-changing target. Areas were frequently added through agreements and were occasionally annulled.

DISCUSSION

The 2006 county prioritization model was a key component of Kentucky's bobwhite restoration plan (Morgan and Robinson 2008). The models' purpose was to help direct personnel, funds, and conservation programs to counties with the highest potential for bobwhite restoration in 10 years. High priority counties were elevated in placement for Farm Bill biologists, considered in Wildlife Habitat Improvement Program rankings, referenced when modifying Conservation Priority Areas in CRP, and targeted for advertisement and bonus payments in support of Farm Bill conservation programs. The majority of sub-county level focus areas were within high priority counties.

Our approach was a hybrid technique of using ecological parameters, such as grassland and bobwhite presence, coupled with potential for conservation delivery (i.e., targeting production farmers working marginal soil with strong USDA collaboration) (Higgins and Esselman 2006). Knight et al. (2006: 409) contend that "many publications in peer reviewed journals represent systematic conservation assessments, not conservation planning, because they contain no links to processes for developing

Fig. 1. Change in northern bobwhite county prioritization models for 2006 and 2011 in western Kentucky.

implementation strategies or stakeholder collaboration and so are unlikely to be effectively implemented." County prioritization was designed to minimize effort for conservation delivery and maximize likelihood of bobwhite response, and we believe our model delivered that product.

Our models were too coarse for targeted bobwhite habitat restoration efforts. County boundaries as a minimal unit worked well for conservation delivery, but opportunities for bobwhite habitat development are not county-wide in most cases. Habitat restoration efforts could be further delineated in small areas within country boundaries. We believe there is potential for our approach to better prioritize conservation actions, but they should be paired with more sophisticated, finer-scale, conservation mapping such as Twedt et al.'s (2007) biological potential layer for bobwhite or NBCI Version 2.0 (NBTC 2011).

Twedt et al. (2006) focused on bottomland hardwood forest, and suggested biological parameters in conserva-

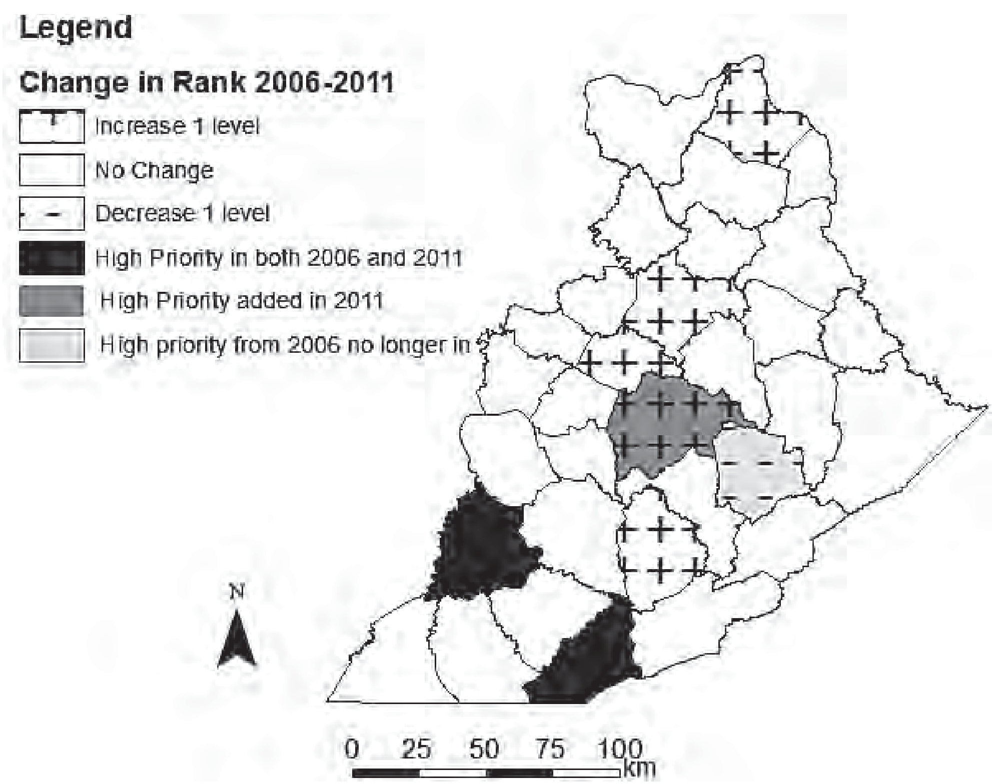

Fig. 2. Change in northern bobwhite county prioritization models for 2006 and 2011 in eastern Kentucky.

tion implementation should be paramount as socio-economic considerations are more fleeting (e.g., subject to commodity prices or changes in government programs). We agree societal measures alone should not drive ecological planning, but they must be a major contributor to short- (e.g., < 5 years) and long-term (e.g., > 20 years) conservation actions. Future land use is difficult to predict, but production of crops and energy is likely to expand; conservation prioritization must include parameters to account for those realities.

It is desirable that a county prioritization model is nimble to change in response to socio-economic factors, but the variability among our models across short periods of time was a shortcoming. Annual fluctuations in the county-based data sets could be better controlled by using multi-year averages to stabilize county prioritization. The use of the Jenks Natural Breaks Method should also help control annual variations by grouping data.

Taking advantage of on-the-ground expertise was a unique and powerful component of our prioritization. Field personnel understand the landowner and conservation communities, and their values with respect to natural resource management. Including that perspective can be important to successful conservation delivery. The cost and effort of collecting that information was far less than a statewide human dimensions survey.

Personnel surveys have shortcomings. Personal bias and other uncontrolled variability may erroneously categorize landowner and conservation personnel's interest and capabilities. Staff opinion polls with more objective questions and a minimum 3 to 5 years experience could provide more consistent and accurate measures. By expanding our survey to a broader conservation community (i.e., USDA, cooperative extension), a population of responses for a county could be collected. The result could be a more representative evaluation of the conservation delivery potential for specific counties

We struggled to replicate our modeling procedures despite having written procedures. We believe the 2011 analysis was a strong replicate of the 2006 approach, but time was lost confirming details of the procedure and discussing the 2006 logic of our decision making process. We recommend having a process diagram and written procedures that highlight the logic of the decision making process.

MANAGEMENT IMPLICATIONS

Targeted private lands management is paramount for successful wildlife conservation, including northern bobwhite restoration. Conservation agencies and their partners could improve effectiveness by identifying social conservation targets (e.g., recreational landowners or production farmers using marginal land) that maximize conservation delivery potential at the county level. Data sets can be identified or created and interfaced with those targets within finer biological models. The results of those models could be followed by localized personnel, advertising, and focused conservation programs resulting in habitat on the ground.

NBCI 2.0 was developed by state-based workshops in collaboration with state fish and wildlife agencies (NBTC 2011). Participants were divided into teams to map bobwhite restoration potential including threats and opportunities. This technique was a tremendous step forward, but created a potential conservation delivery bias towards fish and wildlife agency personnel, bias from dominant individuals within teams, and relied on subjective interpretations of conservation delivery potential. Our approach can be modified to address those shortcomings with direct polling of conservation delivery staff with more objective questions and a broader base of conservation delivery personnel. It could serve to enhance or validate NBCI 2.0.

Our models demonstrated conservation delivery targets change over time. Fluctuations in commodity prices, modifications to agricultural programs, and transitions in landowners and conservation delivery personnel can influence habitat enhancement opportunities. The creation of the NBCI 2.0 data set was expensive and arduous. It is unknown when that process will be replicated. A modification of our approach may be the most cost-effective and timely way for states to improve the model in the future.

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LITERATURE CITED

Commission for Environmental Cooperation. 1997. Ecological regions of North America-toward a common perspective. Communications and Public Outreach Department of CEC Secretariat, Montreal, Quebec, Canada.

Dimmick, R. W., M. J. Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Southeastern Association of Fish and Wildlife Agencies, Columbia, South Carolina, USA.

Higgins, J., and R. Esselman, eds. 2006. Ecoregional assessment and biodiversity vision toolbox. The Nature Conservancy, Arlington, Virginia, USA.

Jenks, G. F. 1967. The data model concept in statistical mapping. International Yearbook of Cartography 7:186–190.

Johnson, C. J., D. R. Seip, and M. S. Boyce. 2004. A quantitative approach to conservation planning: using resource selection functions to map the distribution of mountain caribou at multiple spatial scales. Journal of Applied Ecology 41:238–251.

Kentucky Department of Fish and Wildlife Resources (KDFWR). 2010. Kentucky's comprehensive wildlife conservation strategy. Frankfort, USA. fw.ky.gov/kfwis/stwg

Kentucky Division of Geographic Information. 2007a. County boundary polygons of Kentucky. Kentucky Geoportal, Frankfort, USA. kygisserver.ky.gov/geoportal/catalog/search/viewMetadataDetails.page?uuid=%7B42438C18-0D34-47C6-B902-79D6E94BF180%7D

Kentucky Division of Geographic Information. 2007b. Kentucky 2005 Land Cover–Anderson Level II. Kentucky Geoportal, Frankfort, USA. kygisserver.ky.gov/geoportal/catalog/search/viewMetadataDetails.page?uuid=%7B47906D61-FFB5-4A13-BF2A-EB6A14F17040%7D

Kentucky Division of Geographic Information. 2007c. Kentucky NLCD01.Kentucky Geoportal, Frankfort, USA. kygisserver.-ky.gov/geoportal/rest/document?id=%7B0484AA9B-4633-4A36-B212-0C8EC1BE686D%7D

Kentucky State Data Center. 2005. REIS employment by industry charts, Kentucky and counties. Louisville, USA. ksdc.louisville.edu/sdc/reis/empl_by_industry_reisdata.xls

Knight, A. T., R. M. Cowling, and B. M. Campbell. 2006. An operational model for implementing conservation action. Conservation Biology 20:408–419.

McKnight, T. L. 1990. Physical geography: a landscape appreciation. Third edition. Simon and Schuster, Englewood Cliffs, New Jersey, USA.

Morgan, J. J., and B. A. Robinson. 2008. Road to recovery: the blueprint for restoring the northern bobwhite in Kentucky. Kentucky Department of Fish and Wildlife Resources, Frankfort, USA.

National Bobwhite Conservation Initiative (NBCI). 2011. State of the bobwhite 2011 report: grassland conservation at a crossroads. National Bobwhite Technical Committee Publication, Knoxville, Tennessee, USA.

National Bobwhite Technical Committee (NBTC). 2011. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee Publication, Version 2.0. Knoxville, Tennessee, USA.

Prism Climate Group. 2006. Average annual precipitation, 1971–2000, Kentucky. Oregon State University, Corvallis, USA. www.prism.oregonstate.edu/state_products/index.phtml?id=KY

Twedt, D. J., W. B. Uihlein III, and A. B. Elliott. 2006. A spatially explicit decision support model for restoration of forest bird habitat. Conservation Biology 20:100–110.

Twedt, D. J., R. R. Wilson, and A. S. Keister. 2007. Spatial models of northern bobwhite populations for conservation planning. Journal of Wildlife Management 71:1808–1818.

U.S. Department of Agriculture (USDA). 2002. National Agricultural Statistics 2002 census data. USDA, National Agricultural Statistics Service. Washington, D.C., USA www.agcensus.usda.gov/Publications/2002/index.asp

U.S. Department of Commerce. 2004. United States summary: 2000 population and housing unit counts. USDC, Census Bureau. Washington, D.C., USA www.census.gov/prod/cen2000/phc3-us-pt1.pdf#page=44

U.S. Department of Commerce 2009a. Cumulative estimates of resident population change for the United States, regions, states, and Puerto Rico and region and state rankings: April 1, 2000 to July 1, 2009 (NST-EST2009-02). USDC, Census Bureau. Washington, D.C., USA. www.census.gov/popest/states/NST-pop-chg.html

U.S. Department of Commerce. 2009b. Table 825. Farms–number and acreage by state. USDC, Census Bureau. Washington, D.C., USA www.census.gov/compendia/statab/2012/tables/12s0825.xls

Wethington, K., T. Derting, T. Kind, H. Whiteman, M. Cole, M. Drew, D. Frederick, G. Ghitter, A. Smith, and M. Soto. 2003. The KY Gap Analysis Project Final Report. USDI, Geological Survey, Biological Resources Division, Frankfort, Kentucky, USA.