Selection of Focal Areas for Northern Bobwhite Habitat Enhancement on Private Lands in North Carolina

Doug L. Howell, *North Carolina Wildlife Resources Commission, Division of Wildlife Management, 1722 Mail Service Center, Raleigh, NC 27699-1722*

David T. Cobb, *North Carolina Wildlife Resources Commission, Division of Wildlife Management, 1722 Mail Service Center, Raleigh, NC 27699-1722*

Terry L. Sharpe, *North Carolina Wildlife Resources Commission, Division of Wildlife Management, Sandhills Wildlife Depot, PO Box 149, Hoffman, NC 28347*

Abstract: In August 2000, the North Carolina Wildlife Resources Commission approved and funded the Cooperative Upland habitat Restoration and Enhancement (CURE) Program, an initiative to create and maintain early-successional upland habitat for the enhancement of northern bobwhite *(Colinus virginianus)* populations and associated early-successional species in North Carolina. As a part of the initial implementation of the CURE Program, our objectives were to identify specific geographic areas in North Carolina (focal areas) where the potential to restore and enhance bobwhite habitat and increase bobwhite populations on private lands was greatest. We used a Geographic Information System and remotely-sensed satellite imagery to examine current land use and the spatial arrangement of bobwhite habitat to develop a model of landscape suitability for bobwhite habitat restoration and enhancement in North Carolina. Landscape suitability relative to the focal area selection process identified those areas of the state which presently have land use or land-cover types arranged in the landscape in proportions that are likely to support high bobwhite numbers and where bobwhite are likely to respond to management actions and target programs. Based on our model, we identified potentially suitable landscapes and selected focal areas in the western Piedmont and northern and southern Coastal Plain of North Carolina for initial implementation of the CURE Program. Development of landscape models similar to ours can be adjusted to more accurately reflect current land-use patterns within a particular state or physiographic region, and may be more appropriate when objectives are to identify potentially suitable landscapes for targeted management rather than habitat suitability for a given species.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl Agencies 56:159–170

In the southeastern United States, Breeding Bird Survey (BBS) data indicate northern bobwhite (*Colinus virginianus;* hereafter, bobwhite) populations have declined by 3.8% per year during the last 3 decades (Sauer et al. 2000). Declines in bobwhite populations have been associated with deteriorating quantity and quality of habitat (Brennan 1991). Loss of habitat and degradation of habitat quality are largely the result of increased human populations and associated changes in land-use patterns, and intensified agricultural and forestry operations resulting in loss of early-successional habitat and bobwhite food availability (Klimstra 1982, Roseberry and Klimstra 1984, O'Conner and Shrubb 1986, Guthery 1997, Burger 2002). In response to these declines, 2 southeastern states have initiated specific programs that provide assistance to private landowners interested in enhancing bobwhite habitat on private lands. In 1996, The Virginia Bobwhite Quail Plan was initiated by the Virginia Department of Game and Inland Fisheries. In 1999, the Georgia Department of Natural Resources implemented the Bobwhite Quail Initiative. These programs provide technical guidance and cost share funding for habitat enhancement including herbaceous field borders, fallow land, conversion of fescue to native warm-season grasses, hedgerows, center pivot corners, forest openings, and prescribed burning (Burger 2002).

There are many federal and state economic incentive programs to promote soil, water, forest, or wildlife conservation in North Carolina. In general, all these programs provide cost shares to landowners who enroll, and directly or indirectly impact wildlife habitat. Of these, the Conservation Reserve Program, Conservation Reserve Enhancement Program, Wetland Reserve Program, Stewardship Incentives Program, Wildlife Habitat Improvement Program, and North Carolina Agricultural Cost Share Program all provide avenues for landowners to directly improve and manage grasslands and early-successional herbaceous habitats. However, the impact of these programs on bobwhite across North Carolina are unknown. Conversion of rural acreage to urban uses, changes in agricultural habitat, loss of idle farmland, and an increase in intensive timber management have occurred concurrently with bobwhite population declines of 4.5% per year during the period 1966–1999 (Brown 1993, N.C. Dep. Agric. 1998, Sauer et al. 2000).

Previous efforts by the North Carolina Wildlife Resources Commission (hereafter Commission) to reverse declining trends in small game, including bobwhite, have had localized success but have failed to reverse statewide population declines (Hazel and Hanka 1958). We offer that the inability of efforts to reverse statewide trends in bobwhite populations was primarily due to objectives that were inconsistent with the regulatory authority of the Commission (Cobb et al. 2002). Big game restoration efforts have been achievable through direct restoration projects, creation of sanctuaries, and harvest management. In addition, they have been successful because statewide changes in land use favored big game species, thus requiring little direct habitat management by Commission biologists on private lands. Unlike the situation with big game, the Commission has no statewide jurisdiction to change those factors most significantly impacting bobwhite populations in North Carolina, namely increasing human densities, urbanization, land use conversions, large-scale and monotypic agriculture, and intensive forestry.

We suggest that statewide restoration of bobwhite populations is not feasible.

However, there are likely specific areas of North Carolina where the status of bobwhite populations, land-use patterns, and landowner interest may allow targeted programs to increase the availability of quality bobwhite habitat in the landscape. Recent research used modeling, Geographic Information System (GIS) technology, and remotely-sensed data to examine relationships between bobwhite distribution and abundance and landscape composition and configuration to develop models of habitat suitability for bobwhite over large geographic areas (Roseberry and Sudkamp 1998, Schairer et al. 1999, Peterson et al. 2002). A landscape in the context of these studies refers to areas large enough that their composition and configuration can only be discerned remotely, such as at state, regional, or rangewide spatial scales. Bobwhite numbers were higher in diverse, patchy landscapes containing considerable amounts of open land (row crops and pasture-hay-grass) and abundant woody edge (Roseberry and Sudkamp 1998, Schairer et al. 1999, Peterson et al. 2002). The predictive nature of these models allows habitat enhancement for bobwhite to be concentrated in areas that are potentially suitable or likely to support a robust bobwhite population.

In August 2000, the Commission approved and funded the Cooperative Upland habitat Restoration and Enhancement (CURE) Program, an initiative to create and maintain early-successional upland habitat for the enhancement of bobwhite populations and associated early-successional species in North Carolina (Cobb et al. 2002). As part of the initial implementation of the CURE Program, our objective was to identify specific geographic areas in North Carolina (focal areas) where the potential to restore and enhance bobwhite habitat and increase bobwhite populations on private lands was greatest. Specifically, we used GIS to examine current land use and the spatial arrangement of bobwhite habitat to develop a model of landscape suitability for bobwhite habitat restoration and enhancement in North Carolina. Landscape suitability relative to the focal area selection process identified those areas of the state which presently have land use or land-cover types arranged in the landscape in proportions that are likely to support high bobwhite numbers and where bobwhite are likely to respond to management actions and target programs. Once identified, Commission resources and target programs would be concentrated within selected focal areas to restore and enhance early-successional habitat.

We thank Commission biologists who provided assistance in the development of the landscape suitability model and selection of focal areas including D. T. Sawyer, K. B. Knight, J. M. Scruggs, T. M. Padgett, D. O. Baumbarger, T. D. Monschein, T. K. Hughes, and C. W. Betsill. We also thank M. J. Chamberlain, M. J. Peterson, and an anonymous referee for review of earlier drafts of this manuscript.

Methods

North Carolina lies within the Coastal Plain, Piedmont Plateau (hereafter Piedmont), and Blue Ridge physiographic regions of the southeastern United States (Fig. 1). Because the CURE Program would be initially implemented on public lands in the Blue Ridge (Cobb et al. 2002), development of a model of landscape suitability for bobwhite habitat restoration and enhancement was focused within the Coastal

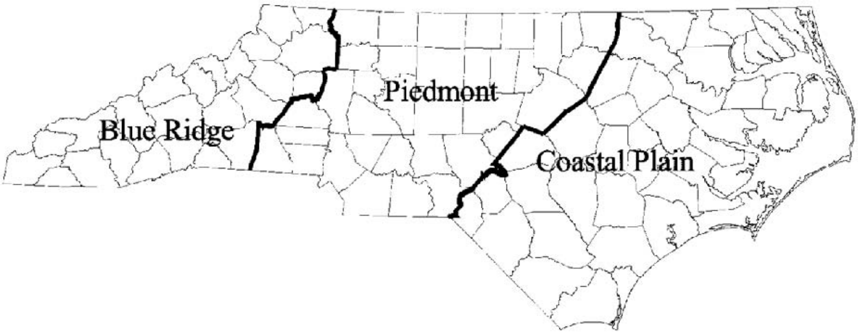

Figure 1. The physiographic regions of North Carolina.

Plain and Piedmont regions of the state. The Coastal Plain and Piedmont encompass approximately 123,000 km^2 and are a matrix of agricultural, pasture, and forest lands. Agricultural lands are largely row and root crops, pastures consist primarily of fescue and alfalfa hay, and forest lands are dominated by pine (*Pinus* spp.), mixed hardwoods, or mixed pine-hardwood stands (Brown 1993, N.C. Dep. Agric. 1998).

We obtained the most current and comprehensive digital land cover data available for North Carolina from the North Carolina Corporate Geographic Database (N.C. Ctr. for Geogr. Inf. and Anal. 1996). Digital land cover data consisted of 23 classes of land use-land cover (N.C. Ctr. For Geogr. Inf. And Anal. 1994) developed from a combination of spectral interpretation of Landsat Thematic Mapper (TM) satellite imagery (1993–1995) and existing GIS data layers (Earth Satellite Corp. 1997) (Table 1). Overall accuracy was >78% and was estimated by comparing the land cover classification against field data at random location (Earth Satellite Corp. 1997).

We used ARCINFO version 8.01 (Environ. Sys. Res. Inst., Inc., Redlands, Calif.) with the GRID extension to manipulate digital land cover data and develop the model of landscape suitability for bobwhite habitat restoration and enhancement. Digital land cover data were converted to ARCINFO GRID format and reclassified by combining many of the 23 original land use-land cover classes (Table 1). We retained the initial pixel resolution of 28.5 × 28.5 m (0.08 ha). The resulting land cover classes (row and root crops, pasture, shrubland, woodland, unsuitable habitat/land use) were developed to identify components of bobwhite habitat most dominant in the North Carolina landscape and empirically related to bobwhite distribution and abundance based upon previous landscape-level bobwhite models (Roseberry and Sudkamp 1998, Schairer et al. 1999, Peterson et al. 2002). In addition, we developed a reclassification procedure that included land cover classes most influential in the success of the CURE Program. Specifically, we included or grouped the original land use-land cover classes likely to be targeted for management, and where grants would be provided to private landowners for restoration and enhancement of early-succes-

Table 1. Reclassification of 23 remotely sensed land use-land cover classes for use in development of a landscape suitability model for northern bobwhite habitat restoration and enhancement in the Coastal Plain and Piedmont of North Carolina, 2000.

Land use-land cover class	Predominant component	Reclassification
Cultivated	Row and root crops, grains	Row and root crops
Managed herbaceous cover	Predominately pasture	Pasture
Upland herbaceous cover	Dry meadows, mountain balds, glades	
Evergreen shrubland	Pocosins, bogs heath balds, maritime scrub	Shrubland
Deciduous shrub	Deciduous shrubs and low woody vegetation, clear-cuts	
Mixed shrubland	Mixed evergreen-deciduous pocosins	
Southern yellow pine	Loblolly, longleaf, slash, shortleaf, Virginia, pond, pitch, table mountain pines	Woodland
Mixed hardwoods	Northern hardwoods, cove hardwoods, mixed oak-hickory	
Other broadleaf deciduous forest	Oak-chestnut-hickory	
Mixed hardwoods/conifers	Mixed hardwood and coniferous forest	
Broadleaf evergreen forest	Carolina bays, pocosins, maritime evergreen forest	
Low intensity development	Between 50% and 80% coverage by synthetic land cover; includes urban/suburban/rural development, asphalt or other building materials	Unsuitable habitat or land use
High intensity development	Over 80% coverage by synthetic land cover	
Riverine-estaurine herbaceous	Salt, brackish, and freshwater marshes	
Bottomland hardwoods	Bottomland and wet hardwood forests	
Needleleaf deciduous forest	Cypress, mixed gum-cypress	
Mountain conifers	White pine, hemlock, spruce-fir	
Other needleleaf evergreen forest	Atlantic white cedar, red cedar	
Oak-gum/cypress	Mixed oak-gum and cypress forest	
Unconsolidated sediment	Beaches, dunes, tidal flats	
Exposed rock	Rock formations, outcrops	
Water	Lakes, rivers, streams sounds, ocean	
No data	Unclassified pixels	

sional habitat (e.g. cropland rental, vegetation control, supplemental plantings, and fencing) (Cobb et al. 2002). Conversely, the inclusion of unsuitable habitat/land use (hereafter, unsuitable habitat) could potentially identify broad geographic areas where habitat or land-use patterns would render the CURE Program largely ineffective.

As the initial step in developing the model, we determined the proportional occurrence of row and root crops, pasture, shrubland, woodland, and unsuitable habitat within 20.2-km^2 of each cell in the reclassified land cover grid (hereafter, RLG). We chose this sized landscape to represent the minimum area required to sustain a viable

Table 2. Landscape condition categories used in the development of a landscape suitability model for northern bobwhite habitat restoration and enhancement in the Coastal Plain and Piedmont of North Carolina, 2000. Each category describes a landscape condition surrounding an individual cell in the proportional land cover grid for each model parameter given the percentage of that parameter within a 20.2-km² landscape.

	Landscape condition					
	Suitable		Marginal		Unsuitable	
Parameter	Coastal Plain	Piedmont	Coastal Plain	Piedmont	Coastal Plain	Piedmont
% row crops	50–70	20–70	40–49	10–19	<40 or >70	<10 or >70
% pasture	0–20	0–40	21–30	41–50	>30	>50
% shrubland	0–10	0–10	11–20	11–20	>20	>20
% woodland	20–40	20–40	41–60	41–60	<20 or >60	<20 or >60
% unsuitable habitat/ land use	0–10	0–10	11–15	11–15	>15	>15

bobwhite population (Rosene 1969, Guthery 2000). We used the FOCALSUM function to calculate total number of cells of each land cover class within a 157 × 157 cell window surrounding a focal cell in the RLG. We determined percentage of each land cover class surrounding a focal cell by dividing total number of cells of each land cover class by total number of cells in the analysis window. This procedure was repeated at every cell in the RLG. The resulting output produced a proportional land cover grid (hereafter, PLG) for each of the 5 land cover classes in the RLG. Cell values in each PLG correspond to percentage of that land cover class within 20.2-km^2 of that cell in the RLG.

We developed a model of landscape suitability for bobwhite restoration and enhancement based upon the proportional occurrence of the 5 land cover classes as defined in each PLG (Table 2). Model parameters included percent row crops, pasture, shrubland, woodland, and unsuitable habitat, each described by a set of mutually exclusive categories. These categories described a landscape condition (suitable, marginal, unsuitable) surrounding each cell given the percentage of each model parameter (e.g., 50%–70% row and root crops) within a 20.2-kn^2 landscape (Table 2). Threshold values for each landscape condition category were based upon review of previous landscape-level bobwhite studies (Michener et al. 1998, Roseberry and Sudkamp 1998, Dailey 1989, Schairer et al. 1999, Peterson et al. 2002), specific objectives of the CURE Program, analysis of each PLG, communication with Commission biologists, and our knowledge of the North Carolina landscape. Because the proportional occurrence of the 5 land cover classes was distinctly different in the Coastal Plain and Piedmont, we defined threshold values independently for each physiographic region (Table 2).

We developed an ARC MACRO LANGUAGE (AML) script to analyze each cell in each PLG and assign an overall landscape condition relative to threshold values in the model. The AML script first analyzed the content (% value) of every cell in each PLG independently and returned a value of 1, 2, or 3, representing an initial landscape condition of suitable, marginal, or unsuitable, respectively, based upon the

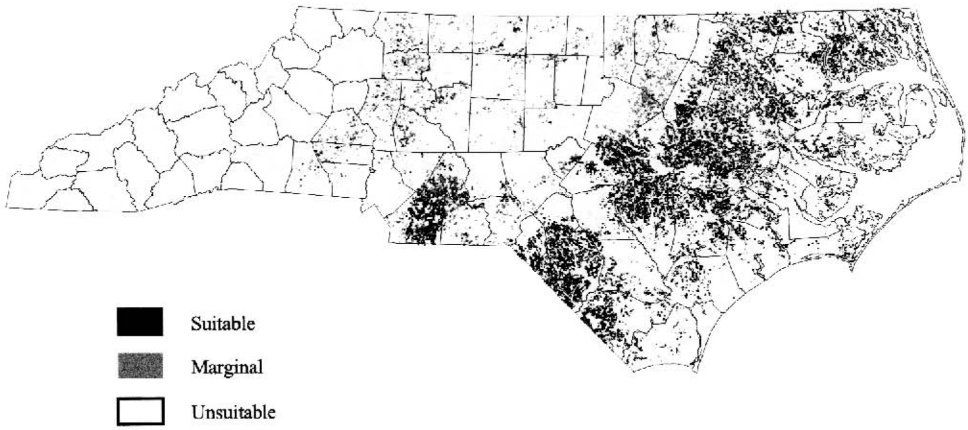

Figure 2. Landscape suitability for northern bobwhite habitat restoration and enhancement in the Coastal Plain and Piedmont of North Carolina, 2000.

threshold values for each model parameter. This process was repeated for both Coastal Plain and Piedmont threshold values. The initial landscape condition values for independent cells were retained in a temporary grid (hereafter, TCG) for each model parameter and physiographic region. For example, a cell in the PLG for row crops with a value of 30 would be assigned a value of 3 (unsuitable) in the TCG for this model parameter in the Coastal Plain, and a value of 1 (suitable) in the Piedmont. The identical cells in the TCG for each model parameter were then analyzed simultaneously to assign a final landscape condition. Final output of the script produced a landscape suitability grid (LSG) for each physiographic region, classifying each cell as having a suitable, marginal, or unsuitable landscape condition (Fig. 2). Only cells assigned a value of 1 in each TCG were given a final landscape condition of suitable in the LSG, otherwise a value of 2 or 3 in either TCG would result in that cell being classified as marginal, or unsuitable, respectively. For example, in the Coastal Plain an individual cell having 60% row crops, 10% pasture, 2% shrubland, 20%woodland, and 8% unsuitable habitat with 20.2-km^2 of that cell would be classified as suitable in the LSG. We interpreted those cells classified as suitable in the LSG for both the Coastal Plain and Piedmont to represent those areas in North Carolina where current land use and the spatial arrangement of bobwhite habitat are likely to support high bobwhite numbers and where the CURE Program would have the greatest success through targeted habitat restoration and enhancement (Fig. 2).

We selected focal areas within both the Coastal Plain and Piedmont by delineating boundaries surrounding clusters of cells classified as suitable in each LSG (Fig. 3). We delineated focal area boundaries to identify those areas of the state where the greatest proportion of the landscape was considered suitable and to establish boundaries within which private landowners would be eligible to participate in the CURE

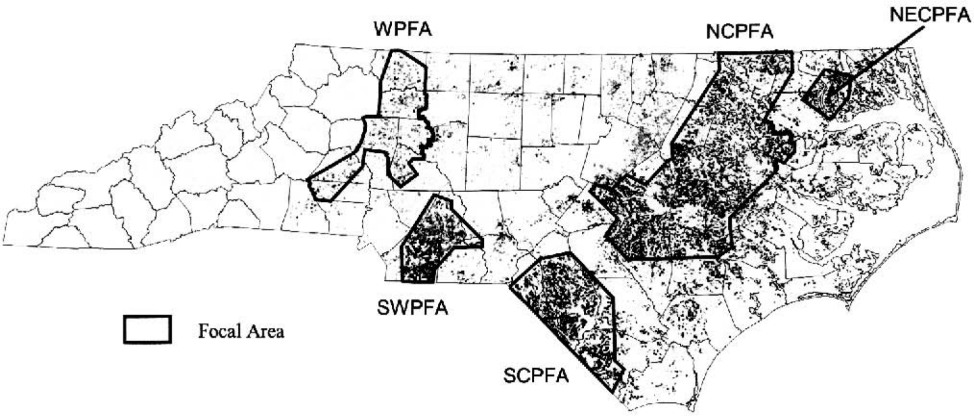

Figure 3. Location of northern bobwhite focal areas in the Coastal Plain and Piedmont of North Carolina including northern Coastal Plain (NCPFA), southern Coastal Plain (SCPFA), northeast Coastal Plain (NECPFA), western Piedmont (WPFS), and southwest Piedmont (SWPFA).

Program. We used political boundaries and physiographic features (e.g., county boundaries, rivers) when appropriate to more clearly define focal area boundaries. (Fig. 3).

Results and Discussion

We developed our model to identify heterogeneous landscapes containing moderate amounts of open land (primarily agricultural cropland and pasture-hay-grass) interspersed with pine, hardwood, or mixed pine-hardwood stands, and with low proportions of urban sprawl or other land cover types classified as unsuitable for bobwhite. Landscape suitability for bobwhite as defined by our model was limited primarily to the upper Coastal Plain and the west, southwest, and northeast portions of the Piedmont of North Carolina. (Fig. 2). Sixty percent of the Costal Plain and over 80% of the Piedmont had land use or land-cover types in proportions classified as unsuitable for initiation of focused habitat restoration and enhancement by the Commission.

Cropland cover is thought to be critically important to bobwhite populations (Brady et al. 1993, Brady et al. 1998) and has been positively correlated with bobwhite abundance across much of its range (Peterson et al. 2002). Landscapes with 50%–60% row crops appeared optimal for bobwhite in Missouri (Dailey 1989), 30%–70% in Illinois (Roseberry and Sudkamp 1998), 30%–35% in Georgia (Michener et al. 1998), and 20%–60% in Virginia (Schairer et al. 1999). Specific objectives of the CURE Program focus largely on the enhancement of nesting, brooding-rearing, and roosting habitat for bobwhite and associated early-successional species on existing cropland acres (Cobb et al. 2002). In North Carolina, agriculture has shifted geographically. Smaller fields and those on less fertile soils, characteristic of the Piedmont region, have been abandoned to pasture or converted to forestry and cropland has been consolidated on more fertile soils in the Coastal Plain (Brown 1993, N.C. Dep. Agric. 1998, Dimmick et al. 2002). We identified agricultural landscapes with 50%–70% row crops in the Coastal Plain and 20%–70% in the Piedmont as potentially suitable. We classified those landscapes containing >70% row crops as unsuitable, including large portions of northeastern North Carolina. Roseberry and Klimstra (1984) and Brennan (1991) hypothesized that increasing field or patch size has a negative effect on bobwhite populations due to loss of edges and larger core field area. Bobwhite numbers were lower in similar landscapes in Missouri (Dailey 1989), Illinois (Roseberry and Sudkamp 1998), and Virginia (Schairer et al. 1999).

Dailey (1998) and Roseberry and Sudkamp (1998) found high bobwhite numbers to be associated with landscapes containing 15%–30% pasture, hay, or grassland. However, they gave no indication of the floristic composition of these habitats. By 1995, over 90% of the land in pasture in North Carolina (occurring primarily in the Piedmont) was planted in tall fescue (*Festuca arundinacea*, N.C. Dep. Agric. 1998). Conversion of native grasslands to exotic grasses and forage, particularly tall fescue, is thought to be a contributing factor in the decline of bobwhite in the southeastern United States (Barnes et al. 1995, Dimmick et al. 2002). Pastures dominated by tall fescue provide poor bobwhite escape, feeding, nesting, and brood-rearing habitat due to lack of proper vegetative structure, floristic composition, and nutritional quality (Stoddard 1931, Barnes et al. 1995). In North Carolina, particularly the Piedmont, we suggest those lands in pasture, as they currently exist, are likely a negative component of the landscape relative to bobwhite abundance. Targeted habitat enhancement for bobwhite within landscapes dominated (>40%) by tall fescue pasture provide fewer management opportunities, is more time consuming, and less cost-effective than that in crop-dominated landscapes, particularly relative to conversion of tall fescue to native forage (e.g., native warm-season grasses). Therefore, we classified large areas within the Piedmont as unsuitable for bobwhite habitat restoration and enhancement.

Early-successional habitat in the form of low, woody deciduous vegetation (primarily clear-cut) is widespread across portions of the eastern Piedmont and southern Coastal Plain of North Carolina, as evidenced by the PLG for that land cover class (shrubland). While temporal in nature, clear-cut can provide good microhabitat conditions for bobwhite by offering freedom of movement at ground level and low overhead protection (Rosene 1969), particularly during the first 2–4 years of forest regeneration, which can favor grass and forb plant communities (Landers and Mueller 1986). However, given the date of collection of the Landsat TM imagery (1993–1995), it is questionable that cells classified as shrubland still exist, as well as benefits to bobwhite, due to canopy closure and subsequent loss of ground cover (Landers and Mueller 1986, Brennan 1991). In addition, cells classified as shrubland occur in greatest proportions in association with large areas of industrial and private timberland (>60% woodland); therefore, we classified few of these areas as potentially suitable landscapes for initiation of the CURE Program.

Landscapes characterized by a relative diversity of evenly distributed cover types occurring in small, well-interspersed patches, and resulting in large amounts of edge, have long been recognized as optimum bobwhite range (Stoddard 1931, Leopold 1933). We used metrics of landscape composition (e.g., percent woodland) rather than landscape structure (e.g., contagion, patch size, woody edge density); therefore, we did not directly measure the extent to which landscape elements were aggregated or clumped, size of landscape patches, or the amount of edge available to bobwhite. The objectives of the CURE Program are to maximize the amount of useable space (Guthery 1997) available to bobwhite over large geographic areas of North Carolina through direct restoration and enhancement of existing land cover. The size of landscape patches and extent to which they are aggregated or clumped, and edge available to bobwhite is an artifact of land-use. We attempted to identify "heterogeneous" landscapes by defining threshold values such that large areas of the state containing monotypic land cover was classified as unsuitable, such as large areas of closed canopy industrial timberland found in the southeastern Coastal Plain and eastern Piedmont.

As outlined previously, we classified much of North Carolina as unsuitable due to large areas of urban development and sprawl, (e.g., the Piedmont), or areas that contained large expanses of unsuitable habitat types (e.g., the Coastal Plain). Future landscape models would benefit from inclusion of an unsuitable parameter, particularly as urbanization begins to "creep" into potentially suitable landscapes or where unsuitable habitat types could render management for bobwhite largely ineffective.

Based on the results of the LSG, we identified 3 focal areas within the Coastal Plain (southern Coastal Plain, northern Coastal Plain, northeast Coastal Plain) and 2 focal areas within the Piedmont (western Piedmont, southwest Piedmont) of North Carolina as potentially suitable landscapes for initiation of the CURE Program by the Commission (Fig. 3). However, we considered the Northeast Coastal Plain focal area to be insufficient in land area to allow for potential future expansion of the CURE Program. While the Southwest Piedmont focal area was classified as suitable at the time of collection of the Landsat TM imagery (1993–1995), this landscape does not accurately reflect current land-use trends. Much of this focal area lies within Union County, North Carolina, one of the fastest growing counties in terms of population in the eastern United States (U.S. Dep. Commerce 2000), therefore much of what was largely rural acreage and classified as suitable has likely converted to urban uses. We selected the southern and northern Coastal Plain, and the western Piedmont focal areas for initial implementation of the CURE Program.

Management Implications

Previous landscape-level models of habitat suitability for bobwhite utilized abundance data (e.g., call counts, harvest data, BBS routes) in developing empirical relationships between landscape composition and habitat suitability (Dailey 1989, Roseberry and Sudkamp 1998, Schairer et al. 1999, Peterson et al. 2002). In contrast, we used a subjective interpretation of published literature on bobwhite habitat suitability for other landscapes and an objective measure of current land use-land cover in North Carolina (i.e., Landsat TM satellite imagery) to develop a theoretical model of landscape suitability for initiation of the CURE Program. While our model did not directly measure habitat suitability for bobwhite, we suggest our model identified those areas of the state where existing land use and land cover provide the best opportunities for the Commission to enhance early-succession upland habitat for bobwhite and associated early-succession species on private lands in North Carolina. The development of landscape suitability models similar to ours can be adjusted to more accurately reflect current land-use patterns within a particular state or physiographic region, and may be more appropriate when objectives are to identify potentially suitable landscapes for targeted management rather than habitat suitability for a given species.

Literature Cited

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue dominated fields. Wildl. Soc. Bull. 23:231–237.

Brady, S. J., C. H. Flather, K. E. Church, and E. W. Schenck. 1993. Correlates of northern bobwhite distribution and abundance with land-use characteristics in Kansas. Pages 115–125 *in* K. E. Church and T. V. Dailey, eds. Quail III: Natl. Quail Symp., Kan. Dep. Wildl. and Parkes. Pratt.

______, C. H. Flather, K. E. Church. 1998. Range-wide declines of northern bobwhite *(Colinus virginianus):* land use patterns and population trends. Gibier Faune Sauvage 15: 413–431.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildl. Soc. Bull. 19:544–55.

Brown, M.J. 1993. North Carolina's forests 1990. U.S. Dep. Agric. For. Serv. Res. Bull. SE-142. Asheville, N.C. 101pp.

Burger, L. W. 2002. Quail management: issues, concerns, and solutions for public and private lands—a southeastern perspective. Pages 20–34 *in* S. J. DeMaso, W. P. Kuvlesky, Jr., F. Hernandez, and M. E. Berger, eds. Quail V: Natl. Quail Symp., Texas Parks and Wildl. Dep., Austin.

Cobb, D. T., T. L. Sharpe, D. Sawyer, and D. O. Baumbarger. 2002. Integrating early-successional wildlife and habitats into North Carolina's 21st Century landscape. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 56:In press.

Daily, T. V. 1989. Modeling bobwhite quail habitat relationships on 4 central Missouri wildlife management areas. Mo. Dep. Conserv., Fed. Aid in Wildl. Restor. Proj. W-13-R-43, Final Rep. 19pp.

Dimmick, R. W., M. J. Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Misc. Publ., Southeast. Assoc. Fish and Wildl. Agencies, Columbia, S.C. 96pp.

Earth Satellite Corporation. 1997. Comprehensive land cover mapping for the State of North Carolina: final report. Off. State Planning, N.C. Ctr. for Geogr. Inf. and Anal., Raleigh. 114pp.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. J. Wildl. Manage. 61:291–301.

______. 2000. Viability of northern bobwhite populations. J. Wildl. Manage. 64:646–662.

Hazel, R. B. and D. J. Hanka. 1958. Nine years of progress in farm game management in North Carolina, 1948–1957. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 11:20–34.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Pages 1–5 *in* F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Talent, eds. Quail II: Natl. Quail Symp., Okla. State Univ., Stillwater.

Landers, J. L. and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Publ. No. 6, Tall Timbers Res. Sta. Tallahassee, Fla. 39 pp.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New Your, N.Y. 481pp.

Mitchener, W. K., J. B. Atkinson, P. F. Houhoulis, P. M. Johnson, R. N. Smith, and J. W. Jones. 1998. Northern bobwhite quail: responses to landscape configuration. Tech. Pap., 64th Annu. Meet. Am. Soc. For Photogrammetry and Remote Sensing, Tampa, Fla. 10pp.

North Carolina Center for Geographic Information and Analysis. 1994. A standard classification system for the mapping of land use and land cover. Off. State Planning, Raleigh. 89pp.

______. 1996. Land use/land cover-TM (APES 1987). N.C. Corp. Geogr. Database, Off. State Planning, Raleigh.

North Carolina Department of Agriculture. 1950–1998. Annual farm census summaries. North Carolina, and North Carolina agricultural statistics. N.C. Dep. Agric., Div. Agric. Stat., Raleigh. 110pp.

O'Conner, R. J. and M. Shrubb. 1986. Farming and birds. Cambridge Univ. Press, Cambridge, U.K. 290pp.

O'Neill, R. V., J. R., Krummel, R. H. Gardner, G. Sugihara, B. Jackson, D. L. DeAngelis, B. T. Milne, M. G. Turner, B. Zygmunt, S. W. Christensen, V. H. Dale, and R. L. Graham. 1988. Indices of landscape pattern. Ecology 1:153–162.

Peterson, M. J., X. B. Wu, and P. Rho. 2002. Rangewide trends in landuse and northern bobwhite abundance: an exploratory analysis. Pages 35–44 *in* S. J. DeMaso, W. P. Kuvlesky, Jr., F. Hernández, and M. E. Berger, eds. Quail V: Natl. Quail Symp., Texas Parks and Wildl. Dep., Austin.

Roseberry, J. L. 1993. Bobwhite and the "new biology." Pages 16–20 *in* K. E. Church and T. V. Dailey, eds. Quail III: National Quail Symp., Kan. Dep. Wildl. and Parks, Pratt.

______ and W. D. Klimstra. 1984. Population ecology of the bobwhite. South. Ill. Press, Carbondale, Ill. 259pp.

______ and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. J. Wildl. Manage. 62:895–902.

Rosene, W. 1969. The bobwhite quail: its life and management. Rutgers Univ. Press, New Brunswick. N.J. 418pp.

Saur, J. R., J. E. Hines, I. Thomas, J. Fallon, and G. Gough. 2000. The North American breeding bird survey, results and analysis 1966–1999. Vers. 98.1. U.S. Geol. Surv., Patuxent Wildl. Res. Ctr., Laurel, Md.

Schairer, G. L., R. H. Wynne, M. L. Fies, and S. D. Klopfer. 1999. Predicting landscape quality for northern bobwhite from classified landsat imagery. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 53:243–256.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, N.Y. 559pp.

U.S. Department of Commerce. 2000. Census of population and housing. Econ. and Stat. Admin., Bur. Census, U.S. Gov. Printing Off., Washington, D.C. 561pp.