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STATEWIDE ASSESSMENT OF WILD TURKEY HABITAT USING SATELLITE IMAGERY IN ARKANSAS

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Abstract: We explored the potential provided by classified digital land cover maps derived from remotely sensed satellite imagery for assessing statewide habitat suitability for eastern wild turkeys (*Meleagris gallopavo silvestris*) in Arkansas. We adapted habitat variables used for ground-based habitat evaluation to classified land cover and assessed quality of the landscape for turkeys by using 2 approaches: a habitat suitability index (HSI) model and logistic regression model. We acquired digital land cover data derived from satellite imagery from the Multi-Resolution Land Characteristics (MRLC) consortium, and computed composition and configuration variables with FRAGSTATS (ArcView Patch Analyst). The HSI model incorporated food and cover variables into a geographic information system (GIS; ArcView Spatial Analyst) and evaluated habitat at a pixel resolution of 30 m. We summarized HSI scores at the county level and regressed against harvest records for wild turkeys. HSI values for the statewide model ranged from 0.52 to 0.79 and explained 32% of the variation in harvest ($r^2 = 0.32$, $n = 68$, $P < 0.05$). Models tailored to each of 4 regions showed habitat suitability ranged from 0.07 to 0.92 and accounted for nearly 70% of the variation in harvest (Ouachita region; adjusted $r^2 = 0.68$, $n = 13$, $P < 0.05$). We used logistic regression to derive a habitat model by comparing land cover characteristics and harvest. We identified 2 variables as most often associated with low harvest of wild turkeys statewide: percentage of land in Row Crops ($\chi^2 = 10.08$, df $= 1$, $P < 0.002$) and percentage of land in Commercial-Industrial-Transportation ($\chi^2 = 8.96$, df $= 1$, $P = 0.028$). Our findings suggest that NLCD satellite imagery and GIS tools can be used to identify habitat characteristics that allow assessment of the potential of landscapes to support wild turkey harvest. If harvest statistics provide a reasonable surrogate for relative population abundance for wild turkeys, then these models are good indicators of habitat suitability.

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Key words: Arkansas, geographic information system, habitat assessment, habitat suitability, habitat suitability index, harvest, landscape, *Meleagris gallopavo silvestris,* satellite imagery, wild turkey.

Habitat inventory at the statewide scale is costly in time and personnel (Johnson 2003). However, recent advances in satellite image analysis and geographic information systems may allow high quality habitat inventories to be conducted at a much-reduced cost. Our intent was to explore the potential of using digital land cover maps derived from remotely sensed imagery for assessing statewide habitat suitability for wild turkeys.

Most existing habitat models for wild turkeys are designed for application at a local level (Miller et al. 2000). The U.S. Fish and Wildlife Service identified several ground-based variables (e.g., average height of

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herbaceous canopy and percent tree canopy cover) for the summer food/brood, fall/winter/spring food, and cover components of their HSI model for the eastern wild turkey (Schroeder 1985). However, ground-based evaluations are difficult to implement statewide because of their labor-intensive nature.

Satellite imagery could allow wildlife managers the opportunity to apply habitat evaluation procedures statewide using GIS. Effectiveness of HSI models is dependent on their ability to capture habitat requirements so that GIS-based variables adequately represent the life requisites (Donovan et al. 1987). The wild turkey is a potentially good candidate for landscape-level models because habitat quality for turkey populations has a spatial component related to arrangement of habitat elements across large geographic areas (Gustafson et al. 1994). Research in New York demonstrated that transforming traditional variables into landscape-level variables that are applicable to satellite imagery can create models for habitat evaluation of wild turkeys (Glennon and Porter 1999, Fleming and Porter 2001). However, these previous studies were limited to smaller regions within a state.

In this study our objectives were to examine potential for logistic regression models developed from satellite imagery to distinguish between high-quality and low-quality habitat for wild turkeys, and compare regional and statewide assessments of habitat suitability indices for wild turkeys.

STUDY AREA

This study was conducted in the state of Arkansas. Arkansas is composed of 4 principal physiographic regions: the Ozark Mountains, Ouachita Mountains, the Gulf Coastal Plain, and the Mississippi River Alluvial Plain or Delta (Hanson and Moneyhon 1989; Figure 1). Elevation throughout the state ranges from 17 m in the Delta region to 839 m in northwestern Arkansas.

The Ozark Mountain region in northern Arkansas contains highlands characterized by flat-topped mountains and narrow ridges with steep-sided valleys (Smith 1989). This region consisted of upland hardwood forests with some conifers and contained most of the 485,000 ha Ozark National Forest. Dominant species included oak (*Quercus* spp.), hickory (*Carya* spp.), maple (*Acer* spp.), cedar (*Juniperus virginiana*), and pine (*Pinus* spp.).

The Ouachita Mountain region extends across the west-central portion of Arkansas and contains the Arkansas River Valley. East-west trending ridges and valleys are characteristic. Pine-hardwood forests were found throughout the Ouachita region and the 666,046 ha Ouachita National Forest was within this region. These forests were predominantly loblolly pine (*P. taeda*) and shortleaf pine (*P. echinata*) with scattered hardwoods (Hanson and Moneyhon 1989) and were managed for timber production.

The Gulf Costal Plain has flat to rolling topography. This region covers the portion of Arkansas south of the Ouachita Mountains. Commercial forestry operations were the dominant economic land-use in this region (Hanson and Moneyhon 1989). Pine-hardwood forests of similar composition to the Ouachita Region were found in the Gulf Coastal Plain.

The Delta region of Arkansas covers the eastern portion of the state. Topography is flat and contains rich though poorly drained soil. Land use in this area was predominantly agriculture: rice, soybean, and wheat were the primary crops (Hanson and Moneyhon 1989). Bottomland hardwood forests persisted along major river valleys in the Delta region. Bald cypress (*Taxodium distichum*) and tupelo (*Nyssa* spp.) were found in wetland areas. Drier riverbanks supported black willow (*Salix nigra*), water hickory (*Carya aquatica*), river birch (*Betula nigra*), and cottonwood (*Populus deltoides*). The northern portion of this region was covered with upland hardwood forests of oak and hickory (Hanson and Moneyhon 1989).

METHODS

To evaluate the potential of habitat assessment using satellite imagery, we sought variables that could be measured from classified land cover using GIS and assessed their ability to characterize habitat suitability. We used 2 approaches to identify variables. First, we designed an HSI model to evaluate the quality of the landscape based on variables that could be measured from classified land cover. Second, we employed logistic regression to select habitat variables empirically from among those variables measurable with classified land cover. We used harvest data, an index of relative abundance, as an independent index of habitat quality for validation of HSI models and as the dependent variable in logistic regression. We created statewide and regional models for both HSI and logistic regression analysis for comparison. We used Statistical Analysis System (SAS) software version 8.1 (SAS Institute 1990) for assessing the models.

Satellite Imagery

National Land Cover Database (NLCD) satellite imagery classified by the MRLC consortium was used because data was readily available nationwide and the classification identified land-cover classes appropriate for wild turkey habitat (Figure 1). The imagery consisted of leaf-off Landsat 5 Thematic Mapper (TM) satellite data, nominal-1992 (1988–1993) acquisitions (U.S. Geological Survey 2000). There were 18 land-cover classes included in the Arkansas MRLC modified Anderson level II classification, and the imagery had a resolution of 30 m. At the time of project completion imagery accuracy was unknown; accuracy assessment has since been completed. The pixel-level accuracy for the South-central United States (Region 6) classified land cover was 44% (U.S. Geological Survey 2004).

Population Index

We used wild turkey harvest data both as a direct measure and as a means of estimating relative abun-

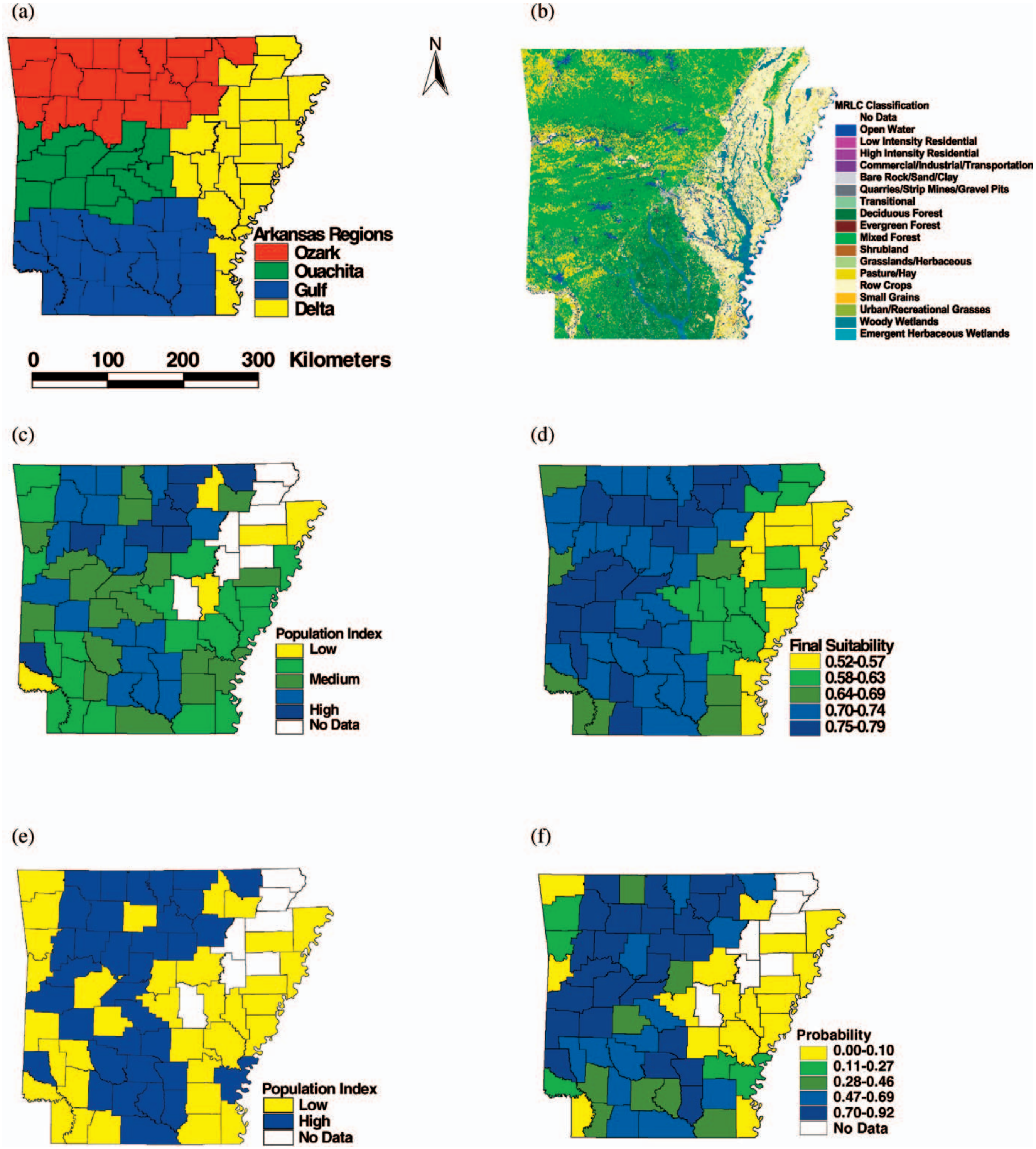

Fig. 1. Habitat assessment for wild turkeys in Arkansas based on 1992 satellite imagery and summarized to county-level resolution. (a) Arkansas counties stratified into the 4 physiographic regions. (b) National Land Cover Dataset satellite imagery for Arkansas. (c) Wild turkey population index used for validation of habitat suitability index (HSI) models for each county. (d) Statewide HSI values summarized at the county level. (e) Logistic regression classification of high or low turkey population index. (f) Logistic regression probability of a county having a high turkey population index.

dance. Lint (1990) demonstrated that harvest data provides a reasonable index of relative abundance. We standardized the index by dividing total harvest by the area of each county. To reduce effects of annual variation in turkey harvest, we used a 6-year (1992–1997) average. We chose the years 1992–1997 because they approximate the time of satellite image collection (1988–1993 vintage). Because many counties were closed to hunting before 1992, using 1992–1997 data allowed for the retention of more counties. The years

Table 1. Habitat suitability index (HSI) values for wild turkey food and cover assigned to the 18 Anderson level-II land-cover classes depicted in 1992 satellite imagery of Arkansas.

Land-cover class	HSI value	
	Food	Cover
Open water	0	0
Low intensity residential	0.5	0.5
High intensity residential	0	0
Com-ind-trans[a]	0	0
Bare rock-sand-clay	0	0
Quarries-strip mines-gravel pits	0	0
Transitional	0.7	0.4
Deciduous forest	1	0.6
Evergreen forest	0.6	1
Mixed forest	0.8	1
Shrubland	1	1
Grasslands-herbaceous	1	0.6
Pasture-hay	1	0.5
Row crops	1	0.5
Small grains	1	0.5
Urban-recreational grasses	0.6	0
Woody wetlands	0.8	0.8
Emergent herbaceous wetlands	0.8	0.8

[a] Com-ind-trans = Commercial-Industrial-Transportation.

1994–1997 extend past the data used for the imagery; however, change in land use was assumed small during this period. Seven counties were closed to hunting at least 1 year from 1992 to 1997 and were excluded from analysis, leaving 68 counties. Harvest data were square-root transformed to approximate a normal distribution (Zar 1999).

Habitat Suitability Index

We developed an HSI model for habitat characteristics measurable with classified land cover based on a review of literature and existing habitat evaluation models for wild turkey (Schroeder 1985, Wigley et al. 1985, Donovan et al. 1987, Hurst and Dickson 1992, Gustafson et al. 1994, Thogmartin 1999). We assigned each land-cover class a value from 0.0–1.0 for food and cover based on quality of that cover class for wild turkeys (Table 1). We combined the food and cover values to yield the final HSI value as:

$$\text{HSI} = (\text{Cover HSI} \times \text{Food HSI})^{1/2}.$$

We used the geometric mean so that a zero value for either food or cover would confer a final HSI value of zero. The imagery was then reclassified (each land-cover class assigned its corresponding HSI value) according to final HSI values using the reclassify function in Spatial Analyst extension of ArcView (Environmental Systems Research Institute 1999). We calculated mean HSI values by county. We assessed the quality of our initial HSI values by fitting HSI versus harvest in a simple linear regression model.

Next, the model was adjusted to tailor fit the HSI values to statewide and regional landscapes. We individually changed the food and cover HSI values (at 0.1 increments) while holding all other model variables constant and fit a new regression model to harvest data. The values producing the best fit were retained for the statewide and 4 regional models. This process was intended to explore the values of the explanatory variables derived from remotely sensed data.

We also summarized HSI values for 1,000 ha polygons to determine how a scale more appropriate to wild turkey use of the landscape influenced the final range of suitabilities. Seasonal home ranges for wild turkeys in the Ozark Mountains and Ouachita Mountains range from 71–1,149 ha (Wigley et al. 1986, Badyaev et al. 1996, Thogmartin 2001). Logistic Regression Model

We developed logistic regression models (Hosmer and Lemeshow 2000) for wild turkey habitat quality based on the LOGISTIC procedure in SAS (SAS Institute 1990). The binary response (dependent) variable was a high or low population index of turkeys (i.e., high or low harvest of turkeys; Figure 1c). The median value of the population index was used to distinguish between high and low densities.

For independent variables in our logistic regression models, we computed composition (amount of a land-cover class) and configuration (arrangement of land-cover classes) landscape metrics from the classified land cover at the county level (the same scale as harvest data) using the Patch Analyst extension of ArcView. This extension calculates landscape metrics using FRAGSTATS functions within the ArcView environment (McGarigal and Marks 1995). Other composition variables computed included human population density, road density and land in public ownership. We obtained human population density and road density (km/ha) from U.S. Bureau of Census data for 1990. We acquired land ownership information from the Gap Analysis Program (Center for Advanced Spatial Technology 1998, Smith et al. 1998).

Variables were selected for the models through a process described by Hosmer and Lemeshow (2000). Univariate analysis was performed on 76 variables; each variable was independently regressed on the dependent variable (Y). Those with P-values <0.25 or those with biological importance were considered candidates for model inclusion. To eliminate redundant FRAGSTAT metrics, variables with Pearson correlation coefficients >0.8 were excluded from further consideration. After univariate and correlation analysis, 20 variables were retained. Next, an *a priori* selection of variables thought to be important to wild turkey habitat and finally forward stepwise selection were used to further reduce the number of variables and produce parsimonious and significant models (Hosmer and Lemeshow 2000). Ten models were identified from which the final state and the 4 regional models were selected. Regional models were explored due to the degree of heterogeneity found among the regions.

We evaluated significance of individual variables and interaction terms through likelihood ratio chi-square tests using the -2 Log Likelihood (-2 Log L) value, a goodness-of-fit statistic describing fit of the explanatory variables in the model (SAS Institute 1990). We judged overall model significance with the likelihood ratio chi-square test (Hosmer and Lemeshow 2000). We used Akaike's Information Criterion (AIC) for comparing different models for the

Table 2. Food (F) and cover (C) values for statewide and regional habitat suitability index models used to assess habitat quality for wild turkeys in Arkansas from 1992 satellite imagery.

	Statewide		Ozark		Ouachita		Gulf		Delta	
Land-cover class	F	C	F	C	F	C	F	C	F	C
Open water	0.1	0.0	0.1	0.0	1.0	0.0	0.1	0.0	0.0	0.0
Low intensity residential	0.0	0.5	0.0	0.5	0.0	0.5	0.5	0.5	0.5	0.5
High intensity residential	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Com-ind-trans[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Bare rock-sand-clay	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Quarry-strip mine-gravel pit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transitional	0.0	0.4	1.0	0.4	0.0	0.4	1.0	0.4	0.7	0.0
Deciduous forest	1.0	0.6	1.0	0.6	0.7	0.6	0.6	0.6	1.0	0.4
Evergreen forest	0.5	1.0	0.9	1.0	0.8	1.0	1.0	1.0	0.6	1.0
Mixed forest	0.9	1.0	1.0	1.0	0.6	1.0	1.0	1.0	0.8	0.2
Shrubland	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Grasslands-herbaceous	1.0	0.6	1.0	0.6	1.0	0.6	1.0	0.6	1.0	0.6
Pasture-hay	1.0	0.5	0.2	0.5	1.0	0.5	1.0	0.5	1.0	0.6
Row crops	0.6	0.5	1.0	0.5	1.0	0.5	0.7	0.5	1.0	0.0
Small grains	0.4	0.5	0.3	0.5	0.3	0.5	1.0	0.5	1.0	0.0
Urban-recreational grasses	0.6	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.6	0.0
Woody wetlands	0.6	0.8	1.0	0.8	0.2	0.8	1.0	0.8	0.8	0.7
Emergent herbaceous wetlands	0.6	0.8	1.0	0.8	0.2	0.8	0.8	0.8	0.8	0.8

[a] Com-ind-trans = Commercial-Industrial-Transportation.

same data (Burnham and Anderson 1992). The models with the lowest AIC values were chosen as the best models.

After variables for statewide and regional models were selected, we tested the assumption of linearity in the logit for continuous variables. We used a grouped, smooth scatter plot to visually assess scale of the continuous variables (Hosmer and Lemeshow 2000). If a covariate was non-linear, then we used a fractional polynomial approach to improve fit of the model ($\mathfrak{p}$ = [−2, −1, −0.5, 0, 0.5, 1, 2, and 3]). Likelihood ratio chi-square tests using the −2 Log L value determined whether a model including transformed variables resulted in a better model fit.

RESULTS

Habitat Suitability Index Model

The best food and cover values after model adjustment varied among the statewide and regional models (Table 2). The best statewide model accounted for 31% of the variation in the population index ($P < 0.001$; Figure 2).

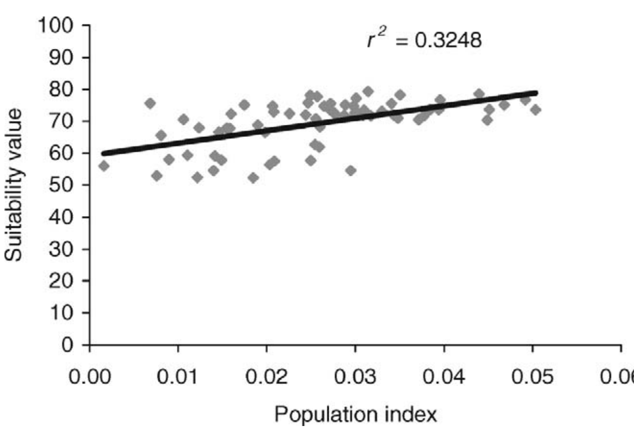

Fig. 2. Regression of habitat suitability by the county-level harvest density for wild turkeys in Arkansas. Habitat suitability is based on 1992 satellite imagery and harvest density is an average of harvest during 1992–1997.

Performance of the statewide model decreased when applied to individual regions except the Ouachita (r^2 = 0.48; Table 3). The statewide model performed worst in the Delta region (r^2 = −0.04). Ozark and Gulf regions were intermediate, but had poor relationships (r^2 = 0.09 and 0.13, respectively).

The HSI values for the statewide model ranged from 0.52 to 0.79 (Figure 1). The statewide HSI values summarized at the regional level identified the Delta region as the area of lowest suitability (0.57). The Ozark, Ouachita, and Gulf regions had average HSI values of 0.74, 0.73, 0.70, respectively (Table 3).

Habitat Suitability Index values for models tailored to each region ranged from 0.07 to 0.92. The Gulf regional model had the highest average suitability (0.82), whereas the Delta region had the lowest suitability (0.22). The average suitability values for the Ozark and Ouachita regions were similar, 0.67 and 0.68, respectively. Habitat suitability values summarized at the 1,000 ha polygon level ranged from 0 to 0.90 (Figure 3).

Models adjusted for regional variation, by altering the initial HSI values assigned to each land-cover class, improved the fit to harvest. By tailoring models

Table 3. Coefficients of determination (r^2) for habitat suitability models for wild turkeys and average county HSI values summarized at the regional and state level in Arkansas, 1992–1997.

Model	Statewide model r^2	Regional model r^2	Average HSI	Average regional HSI
Statewide	0.31		0.69	
Ozark	0.09[a]	0.25[a]	0.74	0.67
Ouachita	0.48[a]	0.68[a]	0.73	0.68
Gulf	0.13[a]	0.35[a]	0.70	0.82
Delta	−0.04[a]	0.10[a]	0.57	0.22

[a] Adjusted r^2 values.

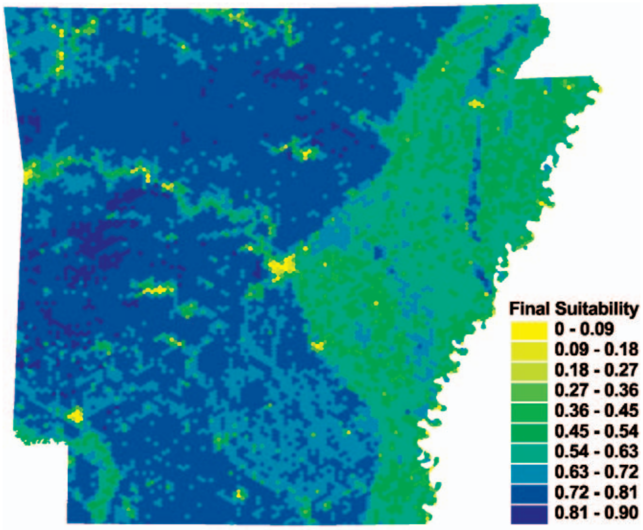

Fig. 3. Statewide habitat suitability index values for wild turkeys in Arkansas averaged to 1,000 ha polygons.

to specific regional characteristics, we were able to account for as much as 68% of the variation in the population index (Table 3). Both the statewide and regional models identified the Delta region as the area of lowest suitability (HSI = 0.22–0.57) and the Ouachita and Gulf regions as the highest (HSI = 0.68–0.82; Table 3). The statewide model showed comprehensive habitat suitability of 0.69; regional suitability values based on the statewide model ranged from 0.57 to 0.74 (Figure 1).

Logistic Regression Model

Only 2 variables were included in the statewide logistic regression model. The probability of a high population index (Figure 1e) was negatively associated with the percentage of Commercial-Industrial-Transportation (Com-Ind-Trans) (χ^2 = 8.96, df = 1, P = 0.028) and the percentage of land in Row Crops (χ^2 = 10.08, df = 1, $P < 0.002$) (Figure 1). The final statewide model created for logistic regression was chosen based on its AIC value of 63.86. Statewide models tested had AIC values ranging from 63.86 to 84.57. The statewide model was significant ($P < 0.05$) based on the Likelihood Ratio Statistic (Table 4):

$$P = \frac{e^{2.6515 - 5.6031 \times \text{Com-Ind-Trans} - 0.0774 \times \text{Row Crops}}}{1 + e^{2.6515 - 5.6031 \times \text{Com-Ind-Trans} - 0.0774 \times \text{Row Crops}}}$$

The range of percentages for Com-Ind-Trans and row crops were 0.03–2.73 and 0.09–77.52, respectively.

The models tailored for the Ozark, Ouachita, and the Gulf region were significant based on the Likelihood Ratio Statistic ($P < 0.05$; Table 4). The lowest AIC values for the regional models compared within regions were 20.36, 17.77, 22.68, and 7.65 for the Ozark, Ouachita, Gulf, and Delta regions, respectively.

Variables retained in the logistic models differed among regions. Wild turkey abundance based on harvest in the Ozark region was inversely related to the

Table 4. Parameter estimates for best predictors of a high population index of wild turkeys in Arkansas based on 1992–1997 harvest records. β is parameter estimate, χ^2 is chi-square test for H_0 when the parameter is equal to zero.

Variable	df	β	SE	χ^2	P
Statewide model (likelihood ratio χ^2 = 36.41*)**					
Intercept	1	2.65	0.72	13.65	0.001
Percent com-ind-trans	1	−5.60	1.87	8.96	0.003
Percent row crops	1	−0.08	0.02	10.08	0.002
Ozark model (likelihood ratio χ^2 = 6.70)**					
Intercept	1	3.00	1.09	7.51	0.006
Percent com-ind-trans	1	−6.19	2.97	4.34	0.037
Ouachita model (likelihood ratio χ^2 = 4.17)**					
Intercept	1	−1.97	1.36	2.09	0.148
Percent evergreen forest	1	0.17	0.10	2.78	0.095
Gulf model (likelihood ratio χ^2 = 10.39)**					
Intercept	1	−3.45	1.46	5.57	0.018
Percent evergreen forest	1	0.11	0.04	6.52	0.011
Delta model (likelihood ratio χ^2 = 3.40*)					
Intercept	1	−8.81	7.08	1.55	0.213
Percent open water	1	1.11	0.96	1.33	0.250

* $P < 0.1$, ** $P < 0.05$, *** $P < 0.001$.

percentage of land in Com-Ind-Trans. Turkey abundance based on harvest was positively associated with the percentage of Evergreen Forest in the Ouachita and Gulf models, and positively associated with the percentage of Open Water in the Delta region. No interaction terms or variable transformations significantly ($P < 0.05$) improved statewide or regional model fit.

DISCUSSION

The principal question in landscape-scale habitat assessment is whether variables identified with satellite imagery can detect habitat characteristics that are biologically meaningful for wildlife. In preliminary work in southwestern New York, Glennon and Porter (1999) detected habitat attributes (e.g., linear edge) from NLCD classified land cover that appeared useful in landscape-scale habitat evaluation for wild turkeys. The application of habitat assessment using NLCD classified land cover in Arkansas was designed to expand evaluation to a statewide context and to ecological conditions that were different from New York.

To explore the use of classified land cover in habitat evaluation, we considered 2 approaches to modeling habitat suitability, and then assessed potential of each of these in light of their ability to relate habitat quality to harvest, and potentially to relative abundance of turkeys. We investigated HSI models and logistic regression. Our interpretation of performance of each of the successful models focused first on configuration and composition variables, the principal information available from satellite imagery. Second, we examined influence of degree of landform heterogeneity among the physiographic regions on model performance, and therefore the scale most appropriate for model development. Finally, we considered model performance in light of the accuracy and resolution of input data (e.g., classified land cover) and data used to develop and assess performance of the models.

Habitat Suitability Index Models

GIS-based models have the potential to work well for turkeys because their habitat requirements can be generalized to simple combinations of forested and open habitats (e.g., Dickson et al. 1978, Glennon and Porter 1999, Fleming and Porter 2001). Models that employed simple combinations of food and cover requirements were found to be the most successful in relating to harvest of wild turkeys in Arkansas. A statewide HSI model explained 32% of the variation seen in harvest, with some regional models explaining almost 70%.

Regional models were more effective at capturing variation than statewide models. This is understandable because relationships between variables in a model can differ depending upon the composition of land-cover classes within each region (Glennon and Porter 1999). Regional tailoring of habitat models allows consideration of differences in natural physiography and land use present within the regions. The Ozark and Ouachita regions are mountainous, while the Gulf and Delta share flat to rolling topography. Forest stands are predominately upland hardwoods in the Ozarks, whereas the Ouachita and Gulf regions have pine-dominated forests with similar compositions. The major land use in the Gulf is commercial forestry, and agriculture dominates the landscape in the Delta region. It is likely that there are different limiting factors to turkey abundance within each region. In the heavily forested regions, open habitat might be limiting, but where agriculture predominates, forest cover is usually the limiting habitat factor.

However, the fact that the statewide models worked as well as they did is also surprising. In general, most habitat models can only be expected to explain half of the variation in a population's abundance (Morrison et al. 1998). While habitat is important, the relative abundance of wild turkey populations is also influenced by other factors (e.g., predation, reproductive success, weather, disease, legal harvest, and poaching). Previous studies in Arkansas and Mississippi have suggested that nest predation is an important limiting factor in the Ozark and Ouachita Mountains (Seiss et al. 1990, Badyaev 1995, Thogmartin 1999, Thogmartin and Johnson 1999). Populations in northern Missouri, Kentucky, Alabama, and Virginia and West Virginia suffered high (20–40%) rates of mortality due to poaching (Wright and Speake 1975, Fleming and Speake 1976, Kurzejeski et al. 1987, Pack et al. 1999). However, illegal kill rates of 10% were considered negligible in affecting turkey populations in central and east-central Mississippi and the Ouachita Forest of Arkansas (Palmer et al. 1993, Miller et al. 1998, Thogmartin and Schaeffer 2000).

Logistic Regression Models

Several composition and 1 configuration measurement proved useful in creation of habitat models built on logistic regression. The variables selected by logistic regression relate well to our understanding of the ecology of wild turkeys, identifying commercialized areas and areas with large amounts of agriculture as limiting to turkeys. For example, Cleveland County had 0.03% of land in the Commercial-Industrial-Transportation land-cover class and 1,000 turkeys harvested/10,000 km^2. Pulaski County had the largest percentage of land in the Com-Ind-Trans cover class (2.73%) and had a harvest density of 200 turkeys/10,000 km^2. The Com-Ind-Trans cover class includes infrastructure (e.g., roads, railroads) and all highly developed non-residential areas. High Intensity Residential includes housing developments with apartment buildings or row houses where <20% of the area is vegetation. Commercial or industrial areas and areas that are used for transportation would not meet minimum food and cover requirements for wild turkeys. Alternatively, presence of these variables may be a reflection of the lack of hunting in urban and suburban landscapes.

Polk and Poinsett County had 0.09% and 77.52% of land in Row Crops, with respective turkey harvest densities of 600 turkeys/10,000 km^2 and 3 turkeys/10,000 km^2. Row crops can be an important source of food for wild turkeys, but do not provide cover year-round. There is variability associated with the amount of cover needed by turkeys, but areas with extensive agricultural fields (e.g., Delta region) provide little habitat for cover and are less suitable for wild turkeys. Landscapes that feature single crops over extensive areas are negatively associated with wild turkey abundance (Hurst and Dickson 1992). Kurzejeski and Lewis (1990) found that turkeys in northern Missouri rarely used croplands not bordered by mature timber stands. Increasing amounts of woody cover improved poult survival from 0–4 weeks posthatch, in an agriculture-dominated landscape in Iowa (Hubbard et al. 2001). Flather (1989) found a negative association between turkey densities and area in cropland and human related land-uses in the context of a landscape-scale analysis of the southern United States.

Some of the variables identified are likely surrogates for biologically meaningful variables that are not easily discerned from classified land cover. The percentage of Open Water identified in the Delta region is an example of a possible surrogate variable for bottomland hardwoods. The hardwood forest type associated with river drainages is known historically to be among the best quality habitat for wild turkeys in Arkansas (Meanley 1956). Remnants of this cover class persist along the major waterways. Bottomland hardwood should be classified in the Woody Wetland land-cover class and this type should serve as a better predictor of habitat. However, wetland areas are difficult to delineate with satellite imagery alone (Yang et al. 2001). Ancillary data sources (e.g., National Wetlands Inventory data) are often used to improve wetland detection, but are not always available. Confusion between water and wetland areas would also contribute to inaccuracies. Additional data collection in the field targeting these important, but hard to detect land-cover classes could improve variables used in model development.

Satellite Imagery and Scale

The spatial arrangement of open and forested habitats is an important factor in habitat quality for wild turkeys (Schroeder 1985, Gustafson et al. 1994). We therefore expected configuration variables to be identified as important in the Arkansas models. Research in New York has also explored the use of variables measured from NLCD satellite imagery, and identified configuration in addition to composition variables relating to measures of turkey abundance. In New York, 56% of the variation in turkey harvest was explained by amount of open area and 29% by edge (Glennon and Porter 1999). Fleming and Porter (2001) found that 47% of the variation in poult survival was explained by the Forest Core Area Standard Deviation habitat variable.

The importance of edge and core area variables did not translate to Arkansas landscapes. Edge (the interface between forest and open areas) is important for nesting habitat for wild turkeys and travel corridors for dispersal and was found to be an important habitat variable in New York (Glennon and Porter 1999, Fleming and Porter *this volume*). Thogmartin (1999) found that 9% of the forest patches in an Ouachita study site consisted entirely of edge habitat. Edge habitat was used less than expected for nesting habitat, potentially in response to increased predation in ecotones in Arkansas.

A second explanation for the lack of success of variables characterizing edge habitat in the Arkansas model may be related to the scale of the analysis. Both the scale of assessment and the population data in New York were based on township-level (approximately 10,000 ha) analysis in contrast to county-level analysis in Arkansas. Counties are large enough that they likely contain substantial variation in amount and configuration of edge. Summarizing this variation into a single value may reduce the information and obscure this relationship. For instance, the key habitat component of the Delta region is the small amount of remaining bottomland forest. Percentages of this land-cover class per county are small and therefore are not represented well when averaged to the county scale. Increases in amount of bottomland hardwoods would likely result in an increase in abundance of turkeys; however, the county HSI values would not change significantly. Consequently, HSI values at the county level cannot adequately characterize variation in the population index resulting from a rare, but important habitat component.

Harvest data used for the population index extended 4 years past the dates of satellite image collection. If the assumption of minimal land use change during this 4-year period is incorrect, the discrepancy in satellite image dates and dates of harvest data used could have negatively impacted study results. Urbanization and deforestation are land use changes that could impact suitability of turkey habitat during that period. However, due to the large scale (county-level) that landscape metrics were calculated, a small change in land use would likely not affect metric values greatly.

The overall accuracy of the 1992 classified land cover is low (44%). Combining land-cover classes with similar quality for turkeys and using an aggregate of pixels would potentially have improved the accuracy and allowed for more meaningful models. Aggregating confused land-cover classes is 1 method to overcome data shortcomings (Thogmartin et al. 2004).

Thogmartin et al. (2004) found that there were patterns in how errors were distributed and that mapping problems were associated with rare land covers (e.g., Emergent Herbaceous Wetlands). In Region 4 Open Water was most commonly confused with Emergent Herbaceous Wetlands, which was most commonly confused with Woody Wetlands. Collapsing these 3 categories might have resulted in more meaningful variable identification with logistic regression. In addition, to build predictive logistic regression models the smaller regional models would benefit from additional samples to increase predictive ability.

Although meaningful models were identified through this process, the variables identified are not useful to managers. For example, row crops and industrial areas are not target habitats for wildlife management activities. The exploration of HSI values helped to identify additional land-cover classes that could be combined for modeling wild turkey habitat. High Intensity Residential, Commercial-Industrial-Transportation, Bare Rock-Sand-Clay, and Quarries-Strip Mines-Gravel Pits should be aggregated as they have the same quality for food and cover for wild turkeys. In addition, Row Crops and Small Grains should be aggregated. When commonly confused land-cover classes identified in the southeastern United States (Region 4) are considered, Row Crops and Pasture-Hay could be aggregated to improve image accuracy.

MANAGEMENT IMPLICATIONS

Wild turkey restoration programs in most states have ended or are near completion and management objectives are shifting from restoration to managing currently established populations through habitat manipulation and harvest management. Amount and quality of available habitat will limit wild turkey populations in the future. Habitat models using remotely sensed data could be an important tool to monitor habitat composition and configuration.

Quality of the land-cover data is important to consider when building models for assessing habitat. Land-cover classes should be aggregated to reduce redundancy related to wild turkey biology and to potentially improve accuracy when commonly confused land-cover classes are combined. The expectation is that future land-cover data will have improved accuracy.

In states with a large degree of heterogeneity, assessing habitat at physiographic regions will identify more specific variables and provide better model fit. Regional models should provide more information for managers about habitat quality and priority areas for management.

The scale of assessment limits spatial detail and complexity of the models and perhaps overall utility of the approach. Improvement of quality (i.e., collection of effort information) and resolution of population data (increased sample size) would increase the predictive ability of landscape-level models. Variables averaged on a smaller scale capture more variation present on the landscape. The increase in sample size would allow for generation and testing of models with subsets of the data.

Landscape level habitat assessment at a county scale might be best used in a step-down approach to identifying important turkey habitat. After key counties are identified a more detailed assessment could be initiated using aerial photographs or traditional ground-based methods. A landscape level view can be a valuable compliment to local scale habitat information in decision making for long-term harvest goals and habitat management priority areas for wild turkeys.

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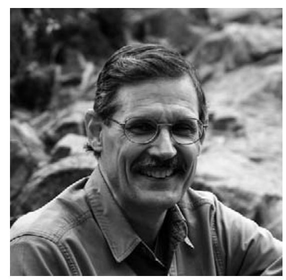

Bill Porter began his studies of the wild turkey in southeastern Minnesota in the 1970s and in collaboration with his graduate students has been exploring questions about populations dynamics and habitat ever since. As a faculty member in Syracuse, he teaches wildlife management, winter ecology and forest ecology. He also directs research and education programs for the university's field station in the Adirondack Mountains of northern New York. He has never been allowed to forget that he once predicted that wild turkeys would not inhabit the Adirondacks.

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