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Testing a GIS Model of Habitat Suitability for a Declining Grassland Bird

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ABSTRACT / Demand for information that can be used to manage loggerhead shrikes has recently increased because of concern over declining populations and loss of open, non-forested habitat. A previously-developed habitat model was modified to predict shrike habitat quality on Fort Riley Military Reservation (FRMR) in Kansas. Shrike habitat suitability indices were calculated based on the amount of potential and usable foraging habitat, and the number of potential nesting sites within a specified area. Interpretation of high quality digital photographs was used to delineate land cover classes, hedgerows and tree counts. These data were entered into a geographic information system (GIS) as individual data sets. The shrike habitat model was then employed to produce a GIS database predicting low, moderate, and high quality shrike habitat throughout the Reservation. Model results indicated that 67% of the Reservation was suitable habitat for loggerhead shrikes. Although over 80% of FRMR was mapped as grassland, the presence of few to several isolated trees or hedgerows was identified as a key factor in modeling habitat suitability. The accuracy of the GIS model was 82% in predicting suitable (moderate and high quality) loggerhead shrike habitat using an independent set of 66 recent shrike observations. The number of potential nesting sites and percent cover of usable foraging habitat were significantly related to habitat suitability of the sites occupied by shrikes.

The application of habitat suitability index (HSI) models is a highly influential tool used by natural resource managers and decision makers to manage wildlife (Brooks 1997). HSI models characterize landscapes with index values (usually ranging from 0 to 1) indicating habitat suitability based on measured features (Schamberger and others 1982). Habitat suitability maps are used routinely for making decisions on land management practices, and for guiding decisions in habitat conservation initiatives such as identifying reintroduction sites for endangered species. Many remote sensing and geographic information system (GIS) applications have been used to develop spatially explicit wildlife habitat maps (e.g., Hodgson and others 1988, Pereira and Itami 1991, Stoms and others 1992, Dale and others 1998). Although some studies include testing with independent data (Lancia and others 1982, Breininger and others 1991, Herr and Queen 1993, Brooks 1997), most habitat suitability models have not been adequately tested (Cole and Smith 1983, Brooks 1997). To move the discussion on the applicability of HSI models forward, we present a test and analysis of a spatially explicit habitat suitability model for a grassland bird species of special concern.

KEY WORDS: Loggerhead shrike; Habitat suitability; Kansas; GIS; Digital photographs; Military

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The loggerhead shrike, *Lanius ludovicianus*, has experienced widespread population declines since about the 1940s (Sauer and others 1995, Yosef and Lohrer 1995, Cade and Woods 1997). Breeding Bird Survey data show a decline of 3.7% per year since 1966 in North America (Sauer and others 1999). Declines have been most acute in the northeastern United States (Graber and others 1973, Morrison 1981) and in eastern Canada where the species is listed as endangered (Johns and others 1994). Populations in the southern Great Plains remain relatively high although declines approach those of other continental populations (Sauer and others 1995).

The causes for the decline remain poorly understood (Busbee 1977, Hands 1989, Yosef 1994), but evidence suggests loss of habitat in the breeding range (Smith and Kruse 1992, Telfer 1992) and in the winter range are important factors (Temple 1995). The loggerhead shrike inhabits grasslands and other sparsely vegetated habitats where scattered woody vegetation and other substrates provide perch sites for foraging (Miller 1931, Kridelbaugh 1983, Bohall-Wood 1987, Gawlik and Bildstein 1990). Characteristics of shrike habitat have been examined in both native (Porter and others 1975, Prescott and Collister 1993, Michaels and Cully 1998) and agricultural hab-

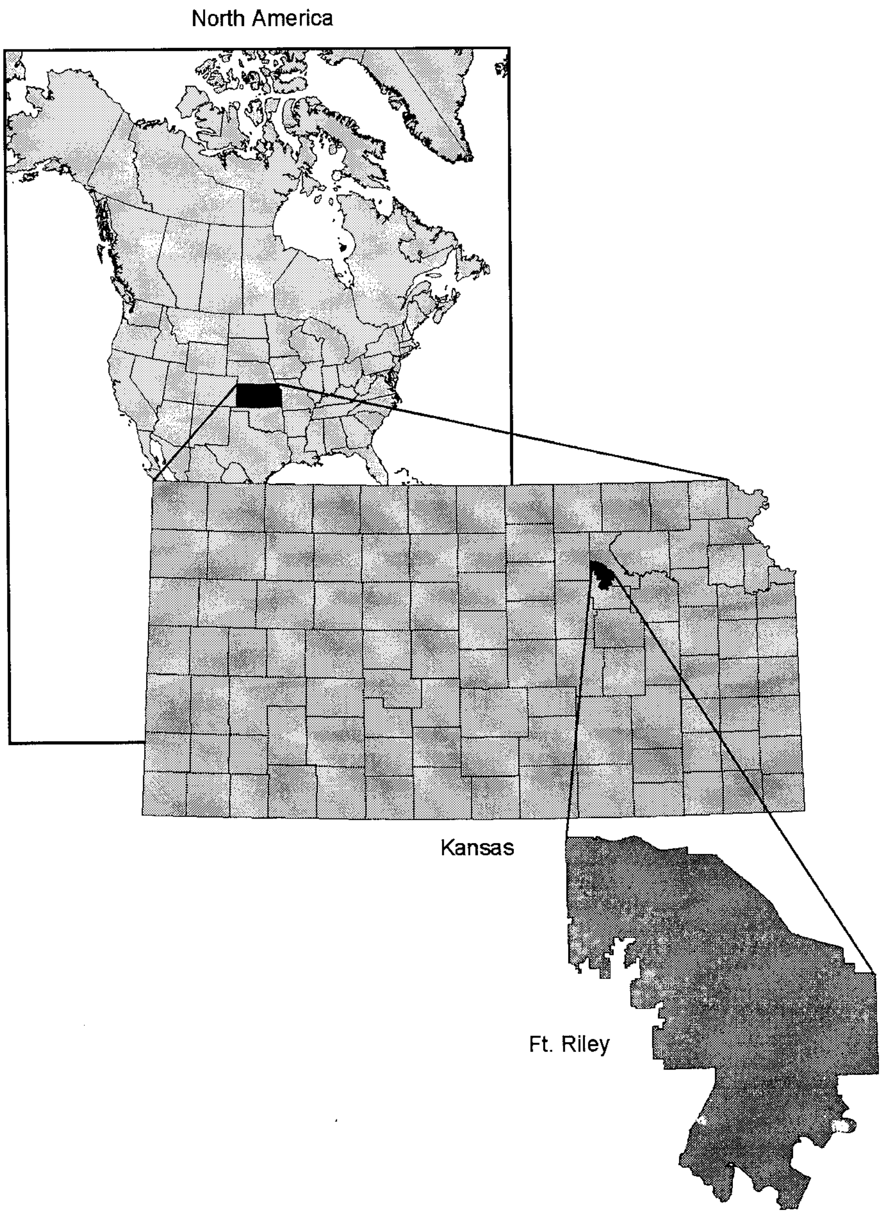

Figure 1. Location of Fort Riley Military Reservation in Kansas.

itats (Kridelbaugh 1983, Brooks and Temple 1990). This study examines habitat characteristics of the loggerhead shrike in native tallgrass prairie on Fort Riley Military Reservation (FRMR) in eastern Kansas. Using a GIS model, we predicted the distribution and amount of suitable habitat on FRMR, tested the model with independent observations, and determined landscape features most important in predicting shrike presence.

Study Area

Fort Riley Military Reservation is a 41,356 ha infantry training center located in northeastern Kansas (Figure 1). The Reservation is in the Flint Hills physiographic province (Schoewe 1949), an area of shallow-soiled uplands overlaying Permian limestones and shales. Historically, tallgrass prairie dominated the uplands of the Flint Hills, and woodlands were confined to stream and river valleys and other topographical features protected from fire. Today, native tallgrass prairie remains the major land cover type on the Reservation and in the Flint Hills as a whole. Areas formerly in cropland on the Reservation have reverted to grassland. Extensive areas of woodland occur along streams, and hedgerows, shrubs, and isolated trees are scattered in uplands. Common upland woody species providing perch sites

Table 1. Description of habitat variables (adapted from Brooks and Temple 1990) used in determining shrike habitat quality

Model Variable	Description
X_1	Percent cover of potential foraging habitat (i.e., grassland)
X_2	Percent cover of usable foraging habitat (i.e., potential foraging habitat within 18 m of an elevated perch) expressed as follows: $X_2 = 36H + T\pi(18)^2$ where H = the length of hedgerows and T = number of isolated trees
X_3	Number of potential nesting trees in the plot, expressed as follows: $X_3 = T + H/5$

for shrikes include dogwood (*Cornus drummondii*), slippery elm (*Ulmus rubra*), honey locust (*Gleditsia triacanthos*), osage orange (*Maclura pomifera*), and sumac (*Rhus glabra*).

Grassland management includes both haying and controlled burns, with about 25 to 33% of the grassland burned each year on a rotational basis (U.S. Army 1994). No livestock grazing occurs on the Reservation. Military training operations are dispersed throughout the Reservation, creating moderate to heavy disturbance to soil and vegetation in some areas. Grass cover tends to be tall and dense except after fires and where disturbed by mechanized training exercises.

Methods

Shrike Habitat Model

We adopted a shrike habitat evaluation model developed for use in the upper Midwest (Brooks and Temple 1990) and modified the model for use in areas dominated by grassland. Similar to the original model, our model calculates an overall habitat suitability index (HSI) value that indicates the capability of a given area to support loggerhead shrikes. The model contains three primary habitat variables: percent cover of potential foraging habitat, percent cover of usable foraging habitat (i.e., potential foraging habitat within 18 m of an elevated hunting perch), and the number of potential nesting trees within a plot (Table 1). The plot size used to calculate all variables was 10.4 ha. This area was chosen to approximate the size of the largest breeding territories reported in the literature (Miller 1931, Kridelbaugh 1982, Yosef and Grubb 1994).

Because varying levels of foraging cover and tree density affect habitat suitability differentially, suitability

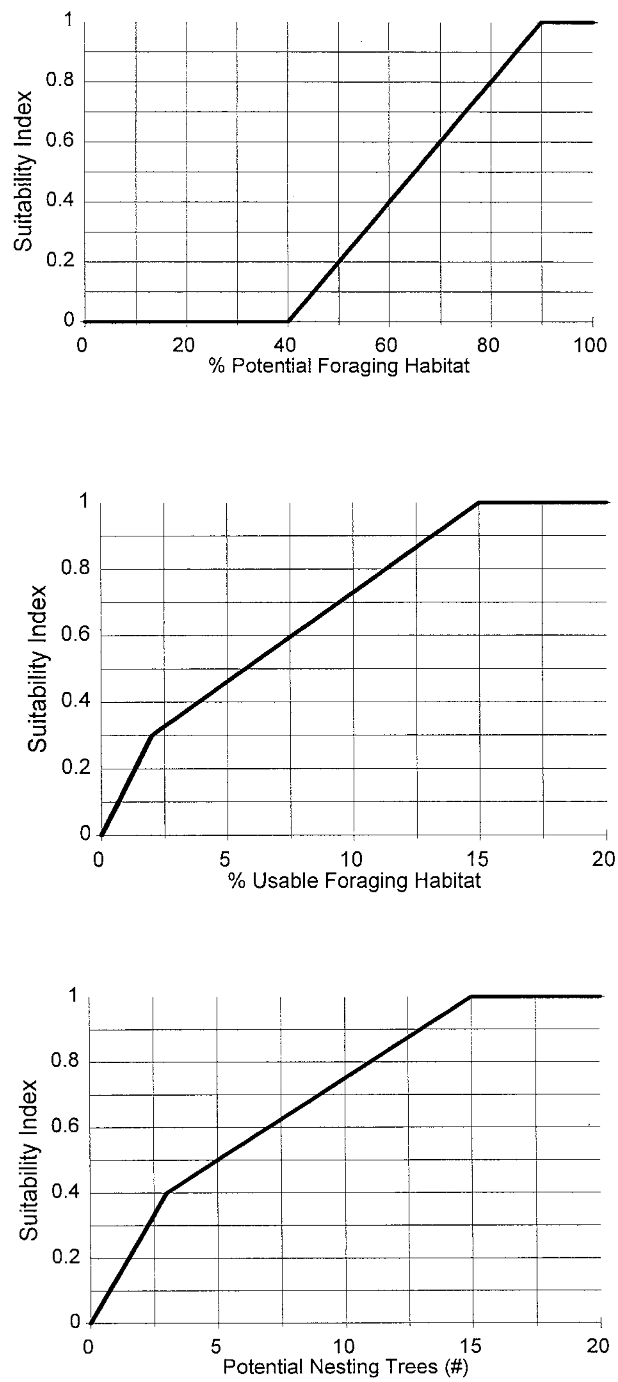

Figure 2. Suitability index curves for three shrike habitat variables (adapted from Brooks and Temple 1990).

index values (SI) were calculated for each variable using index curves. The suitability index curves (Figure 2) used were those of Brooks and Temple (1990) adjusted for the smaller (10.4 ha) plot size used in this study. After determining the suitability index values for all plots, the model was run to calculate the overall habitat suitability value for each plot using the following:

$$HSI = ((SI_1)^2 \times SI_2 \times SI_3)^{1/4}$$

HSI values can range from 0 (unsuitable) to 1.0 (optimal habitat). This range was divided into three evenly spaced classes (0 to 0.33, 0.34 to 0.66, and 0.67 to 1.00) to represent low, moderate, and high quality shrike habitat, respectively.

Remote Sensing and GIS Digital Data

High resolution digital aerial photography provided sufficient detail to map shrike habitat variables. A general land cover GIS data set was created to determine potential foraging habitat. Usable foraging habitat and potential nesting trees were determined by creating separate GIS data sets for hedgerows and tree density. Land cover classes, hedgerows, and tree density were interpreted using 1:12,000 digital orthophoto quarter quadrangles (DOQQs) that were produced from 1991 National Aerial Photography Program (NAPP) black-and-white transparencies (US Geological Survey 1994). Orthophoto products are accurate, geocoded base maps that facilitate interpretation and delineations of landscape features in a GIS by combining the image characteristics of an aerial photograph with the geometric qualities of a map.

The land cover and hedgerow data sets were created by interpreting and digitizing the digital photography using "heads-up" digitizing. The orthophoto was displayed on the monitor and the interpreter delineated areas of homogenous land cover by using a mouse to draw the boundaries. The minimum mapping unit was 0.1 ha. To label polygons, we modified the classification scheme of the Level I categories described in Anderson and others (1976). We delineated five land cover classes: Built Area, Grassland, Woodland, Water, and Sand Bar/Sandy Area (Figure 3). In delineating woodland areas, 15% canopy closure was the minimum figure used to separate wooded areas from other cover types. Woodlands without large openings containing herbaceous vegetation between trees generally do not provide suitable shrike habitat (Miller 1931, Kridelbaugh 1982). Therefore, we assumed that woodlands with ≥15% canopy closure was unsuitable habitat. A photo-interpreter's scale (Carow 1954) was used to determine the percentage of canopy closure for wooded areas on the NAPP transparencies.

Hedgerows were defined as one-tree-wide linear features, with the spacing between tree crowns equal to 18 m or less. This distance approximates the potential foraging span of shrikes (Brooks and Temple 1990). Trees spaced closer than 18 m were considered to contain the same potential foraging area. No distinction was made between naturally-established linear hedgerows occurring along stream courses and those planted as windbreaks. Hedgerows were initially digitized as line coverages and later converted to area features by using a GIS buffer of 6 m. Buffering created a 12 m wide representation of hedgerows, approximating the average width determined from field measurements.

The tree density data set was created using the land cover and hedgerow data sets as visual reference. These data sets were displayed over the DOQQs and counts of isolated trees were calculated for each 10.4 ha plot, yielding a matrix of over 4100 individual cells for the entire Reservation. For each cell, a quick visual inspection of previously identified trees (woodlands or hedgerows) provided a context for counting trees. Tree counts were computed in increments of 5, using a scale of 1 to 5, 6 to 10,. . . . , 31 to 35. The midpoint of each range (e.g., 3 for 1 to 5; 8 for 6 to 10) was assigned to each cell in the GIS database. Identifying trees was often difficult and relied greatly on their contrast with the surrounding landscape, tree shadows (indicating height), and other visual clues. The creation of all data sets and the habitat modeling were conducted using the ArcInfo GIS software package.

Model Testing

Two sets of loggerhead shrike observation data on FRMR were available to independently test the habitat quality model. The first set consisted of 47 shrike sightings observed by staff of the Fort Riley Natural Resources Office during the months of March to June from 1991 to 1993. Mostly observed from roads, these sightings were made incidental to other activities and were independent of habitat quality. Individual sites were recorded on a 1:60,000 topographic map of the Reservation and then georeferenced using the 1991 DOQQs. A second set of 19 loggerhead shrike sightings observed during 1995 and 1996 (from permanent survey points along transects) was available from a concurrent study on the Reservation (Michaels and Cully 1998). Georeferencing coordinates for these observations were obtained in the field using GPS receivers. The GIS data set containing these 66 shrike use sites was used to test the habitat quality model and to identify the most important variables in relating shrike presence to habitat suitability. One-way ANOVA was used to evaluate the strength of model variables and other selected parameters in predicting habitat suitability.

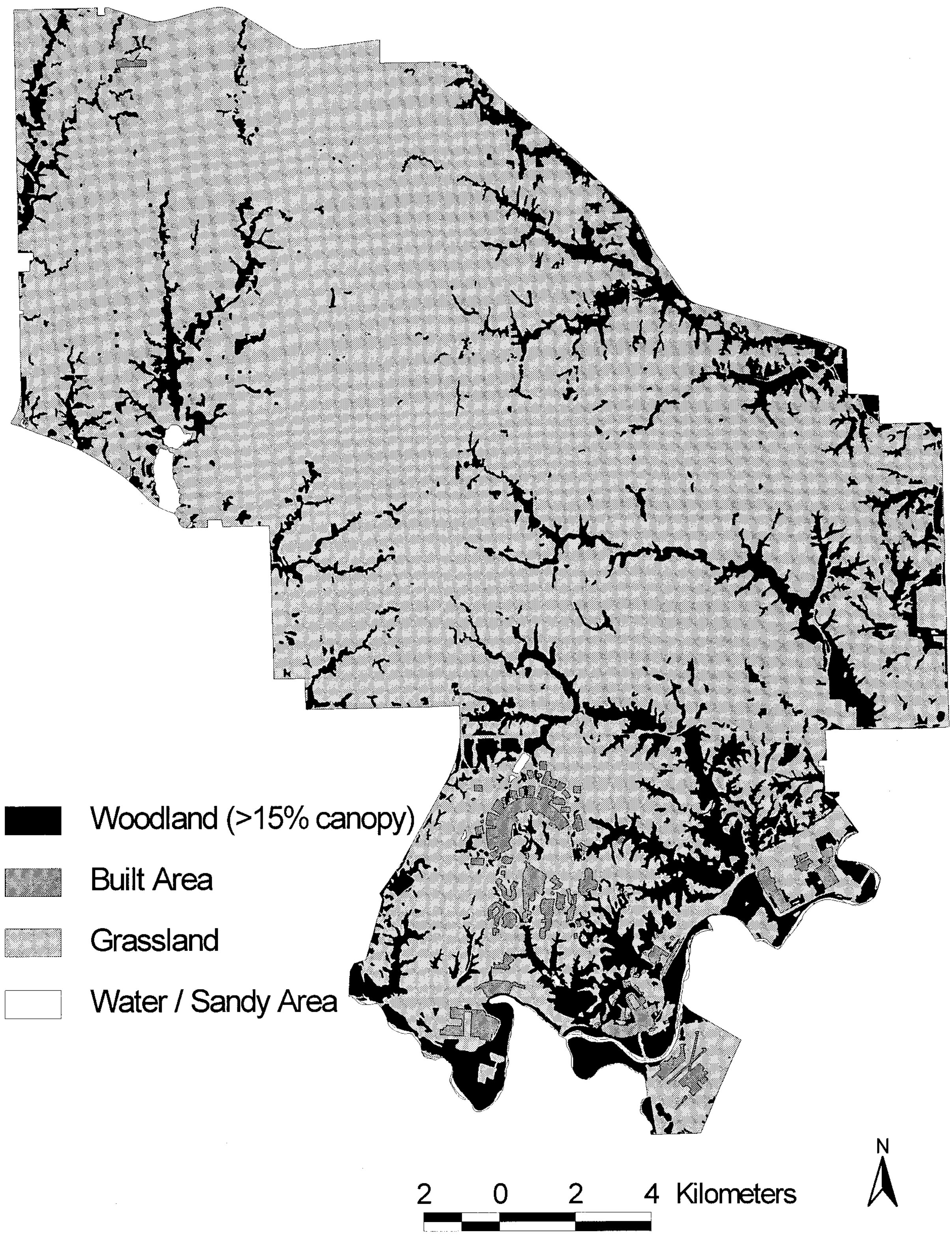

Figure 3. General land cover of Fort Riley Military Reservation derived from interpretation of digital aerial photographs.

Table 2. Habitat suitability index (HSI) values and percent of Fort Riley Military Reservation classified as high, moderate, and low quality shrike habitat

HSI	Habitat Quality	Percent of FRMR	Hectares
1.0	High	13.1	
.89–.99	High	13.7	
.78–.88	High	14.0	
.67–.77	High	4.9	
	Subtotal	**45.7**	**18,899.7**
.56–.66	Moderate	15.2	
.45–.55	Moderate	3.5	
.34–.44	Moderate	2.2	
	Subtotal	**20.9**	**8,643.4**
.23–.33	Low	1.1	
.12–.22	Low	0.8	
.01–.11	Low	0.1	
0.0	Low	31.4	
	Subtotal	**33.4**	**13,812.9**
TOTALS		**100.0**	**41,356.0**

Results and Discussion

Loggerhead Shrike Habitat

The model generated habitat suitability index (HSI) scores across the entire range of values from 0 to 1 (Table 2). The distribution of HSI values indicates that the model was calibrated to the study area (Brooks 1997) and effectively discerned habitat quality differences among sites. The model predicted that high quality shrike habitat is found at sites throughout FRMR (Figure 4). This result was expected in reviewing the land cover map (Figure 3) which indicates that over 80% of the Reservation was classified as grassland, with woodlands (16% of FRMR) occurring mainly to the east and south. Because of the dominance of grassland, most of FRMR (66.6%) was predicted to be suitable habitat (i.e., moderate and high quality) for loggerhead shrikes (Table 2). Other areas were classified as unsuitable habitat (low quality) because of the presence of features avoided by shrikes, including dense forests, built-up areas, and open grasslands lacking isolated woody vegetation.

Independent GIS Model Testing

The GIS model accurately predicted suitable and unsuitable loggerhead shrike habitat, especially when locations of actual shrike observations are compared to the proportions of high, moderate, and low quality habitat expected from the model. Forty-one of the 66 shrike observations (62%) were located on sites predicted to be high qualty shrike habitat (Figure 4), whereas 45.7% of FRMR (Table 2) was classified as high quality habitat. Thirteen shrike observations (20%) were located on moderate quality habitat (20.9% of FRMR), and 12 observations (18%) were located on low quality habitat (33.4% of FRMR). Thus shrikes used high quality sites significantly more frequently than predicted by the GIS model and low quality sites less frequently ($\chi^2 = 11.33$, 2 *df*, $p < 0.005$). When the high and moderate habitat quality results are combined, 82% of the shrike observations (54 of 66) were found on suitable habitat.

Although habitat conditions vary considerably between southern Minnesota and eastern Kansas, our results are similar to those reported by Brooks and Temple (1990). Their model classified habitat into suitable and unsuitable shrike habitat, with 61% of shrike use sites (20 of 33) occurring in suitable habitat. Likewise, the frequency of shrike occurrence in suitable habitat was greater than expected when compared to proportions of suitable/unsuitable habitat derived from their model. Southern Minnesota is an agricultural landscape with large areas of cropland and planted pasture. Brooks and Temple (1990) stated that 45% of their study area was suitable shrike habitat, contrasting with the 68% predicted by our model of FRMR. The largely native and unfragmented grassland vegetation on FRMR (Figure 3) may, in some respects, mimic the combined openness of mixed agricultural land and grassland habitat in Minnesota. In both areas, loggerhead shrike populations are clearly not limited by the abundance of suitable habitat.

Shrike Observations and Habitat Suitability

The most important GIS model variable in predicting shrike habitat suitability was the number of potential nesting trees (X_3; Table 3). Because this variable is a function of both tree density and hedgerow length (Table 1), further analysis was conducted and indicated tree density as the more important feature in determining shrike habitat suitability. Compared to hedgerows, tree density explained greater variation in habitat suitability (Table 3) and had greater correlation (0.574 to 0.445, $p < 0.01$) with the suitability index. The presence of open, woody vegetation that can serve as potential nesting sites is believed to be a significant factor in selection of habitat by breeding shrikes (Brooks and Temple 1990, Yosef and Grubb 1994). However, as the suitability curves in the model predict (Figure 2), habitat suitability does not increase linearly with the number of potential nesting trees. A distribution plot of tree density by habitat quality (Figure 5) indicates that shrikes appear to be selecting grassland habitats that contain low to moderate levels of isolated tree cover. Of the 12 shrike observations occurring on habitat classi-

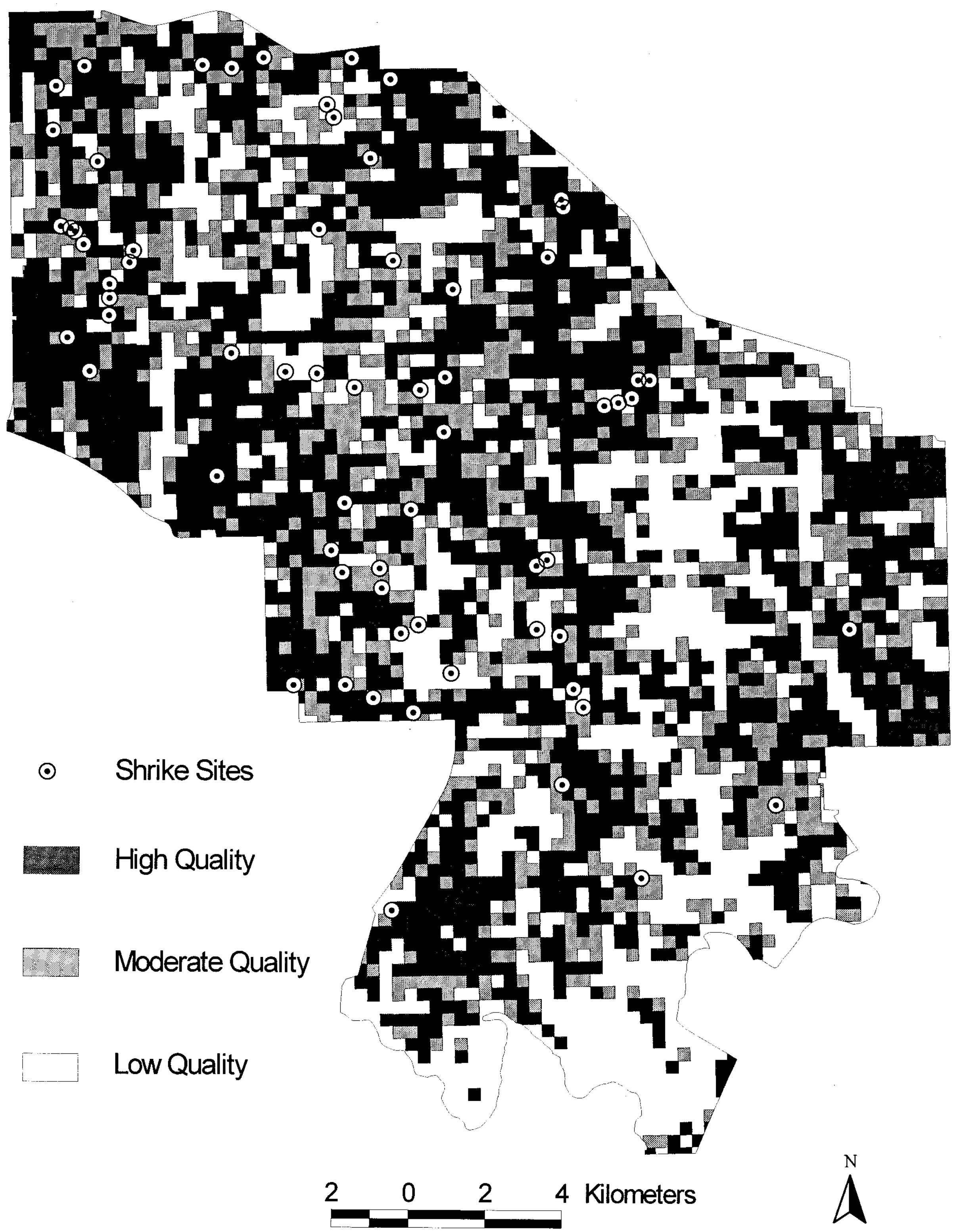

Figure 4. Map of loggerhead shrike habitat quality and 66 shrike observations on Fort Riley Military Reservation.

Table 3. Regression equations between GIS model variables and selected parameters and the dependent habitat suitability index

Linear Regression Models	*F*	r^2	*p*
y = 0.097–0.882 (X_3 or potential nesting trees)	440.96	0.87	<0.001
y = 0.142–0.884 (X_2 or usable foraging habitat)	193.64	0.75	<0.001
y = 0.497–0.024 (number of trees)	31.41	0.32	<0.001
y = 0.577–0.001 (hedgerow length)	15.79	0.20	<0.001
y = 0.267–0.438 (X_1 or potential foraging habitat)			NS

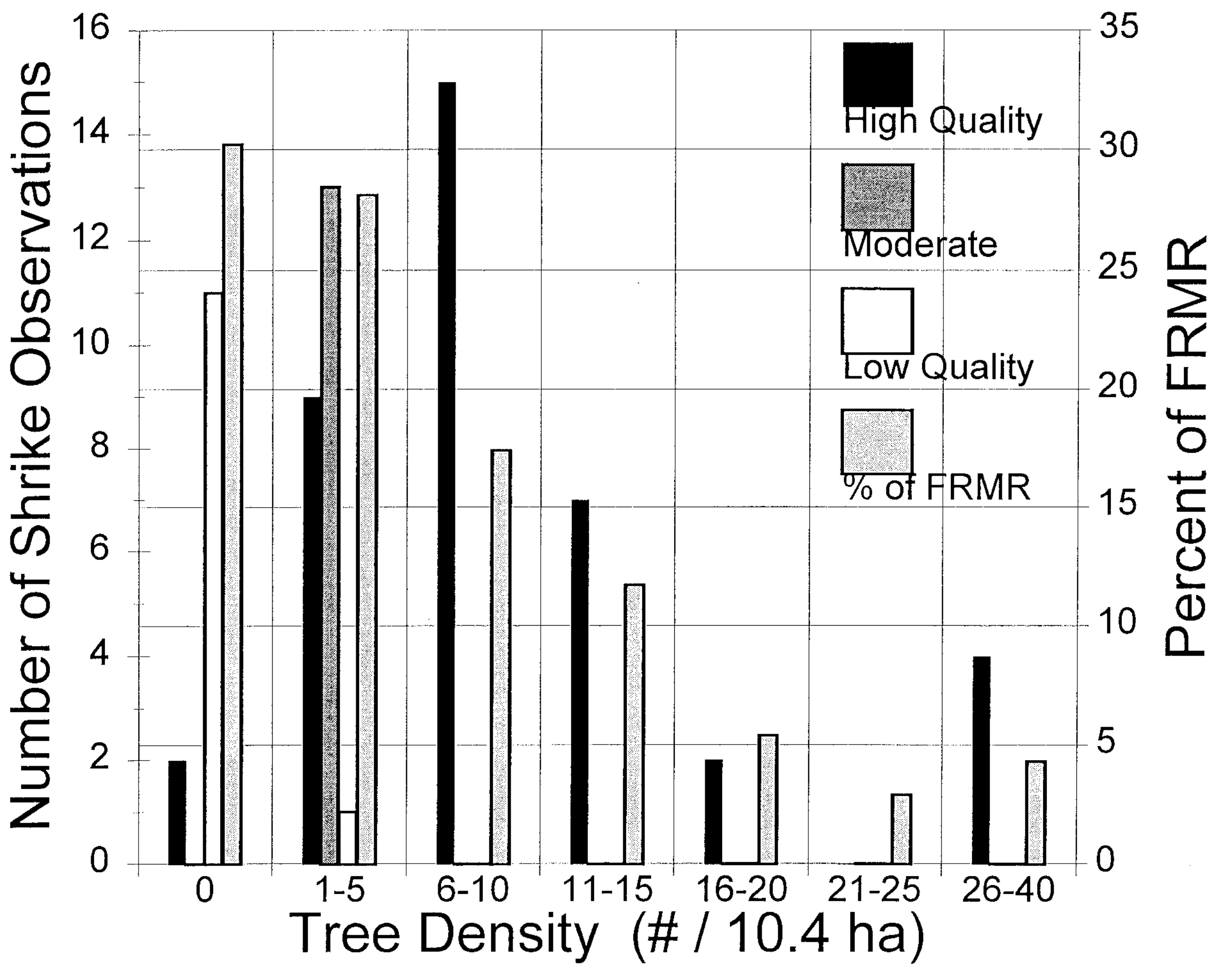

Figure 5. Number of loggerhead shrike observations by tree density and habitat quality.

fied by the GIS model as low quality, 11 were on plots that, based on photointerpretation, did not contain any isolated trees or hedgerows. Our lack of detection of isolated woody vegetation on these plots rendered them as unsuitable shrike habitat. However, shrikes could have been using shrubs, saplings, or telephone poles on these plots which were not detectable from the digital photographs. Our results support the conclusions by Michaels and Cully (1998) that loggerhead shrikes prefer savanna habitat to open grassland and woodland edge.

Usable foraging habitat (X_2) also explained significant variation in habitat suitability (Table 3). This result was expected because isolated trees and hedgerows provide elevated foraging perches for shrikes, and therefore the number of foraging perches determines the total area over which shrikes can forage.

The percent cover of grassland or potential foraging habitat of sites occupied by shrikes (X_1) was not related to habitat suitability. This finding can be attributed to the predominance of grassland on the Reservation. An overlay of shrike observations on the land cover map showed that 64 of the 66 observations were located in grasslands, with only two sightings occurring on woodlands. Thus, potential foraging habitat was the only GIS variable that could not predict habitat suitability of the sites occupied by shrikes.

The use of high resolution remotely sensed data to evaluate shrike habitat suitability had distinct advantages. Manual interpretation of digital aerial photography allowed for relatively quick and efficient development of the key modeling variables (land cover, potential nesting trees, hedgerows) for an extensive area (> 41,000 ha). The black-and-white photography was inexpensive compared to other remotely sensed data, and isolated trees could readily be identified using their shadows to indicate tree height.

However, some fine-scale habitat features that may prove important to shrike habitat suitability (e.g., low woody vegetation, grassland composition and structure) could not be discerned from the photography. Of the 12 shrike observations occurring on habitat classified by the GIS model as low quality, 11 were on plots where no woody vegetation was recorded. One explanation for this result is that small patches of woody vegetation did occur on these 11 plots that were not detectable using aerial photography. Alternatively, shrikes inhabiting habitats with tall herbaceous vegetation may be less dependent on woody vegetation for elevated foraging perches (Chavez-Ramirez and others 1994). Grassland composition and structure on FRMR varies temporally and spatially with many factors including frequency of disturbance by fire, haying or mechanized training exercises. Detecting and modeling fine-scale herbaceous features was beyond the scope of our model.

At the landscape scale, loggerhead shrikes are believed to prefer grassland vegetation with scattered trees and shrubs (Chavez-Ramirez and others 1994, Michaels and Cully 1998). Prediction of areas that contain biophysical properties that meet the target organism's requirements is often the real objective of GIS models of rare species habitat (Dale and others 2000). Although imperfect, our GIS model performed well in detecting key landscape features to identify the preferred habitat of the declining shrike and in predicting shrike distribution.

Conclusions

By successfully integrating habitat suitability modeling in a GIS system, the landscape of a large military reservation in eastern Kansas was efficiently assessed for its ability to support loggerhead shrikes. The GIS model was validated using an independent set of shrike observations, and a model analysis showed the number of potential nesting trees as a significant variable in habitat selection by loggerhead shrikes. Because of its use of general land cover types, the model could be applied to other regions (e.g., eastern United States) that are less dominated by grassland or agricultural land. The use of remote sensing and GIS technologies are recommended for rapid integration of key habitat features at various scales. In the larger context of declining shrike populations and shrinking regional habitat, the Department of Defense has a tremendous opportunity to engage in wildlife conservation on Fort Riley Military Reservation by maintaining its valuable grassland habitats.

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