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MODELING ENDANGERED BIRD SPECIES HABITAT WITH REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT

The Kirtland's Warbler (*Dendroica kirtlandii*) is an endangered bird species indigenous to northern lower Michigan. For its nesting habitat, the warbler requires stands of jack pine (*Pinus banksiana*) growing on the Grayling soil series, a sandy, well-drained soil of glacial outwash plains. These stands, which must be at least 32.4 hectares in size, are generally between eight and twenty-one years old. Ninety percent of all warbler nests have been found within the watershed of the Au Sable River of Michigan.

This research focused on assessing the potential nesting habitat for the species during 1982-83. Landsat Thematic Mapper data were classified and then analyzed using a geographic information system (GIS). Spatial algorithms within the GIS eliminated jack pine stands outside the specified age range, of insufficient area to support optimal nesting sites, and analyzed the shape of each potential habitat patch. Results indicate that this integrated approach has promise for evaluation of potential habitat for the species.

INTRODUCTION

Remote sensing and geographic information systems have been utilized for habitat assessment for several endangered avian species (Breininger et al., 1991; Hodgson et al., 1988; Miller and Conroy, 1990). Recent research on the information content of multispectral satellite data has indicated that information important for habitat assessment (forest community type, stand age, and stand density) may be derivable from the digital data (Horler and Ahern, 1986; Peterson et al., 1986; Spanner et al., 1989; Leckie, 1990). Digital remotely sensed data are readily integrated with other data (e.g., topography, soils, hydrology, others) in a geographic information system (GIS). Additionally, the use of a GIS facilitates the analysis of multiple large data sets, allowing areas that meet specified criteria to be rapidly evaluated for suitability.

The prime nesting habitat for the Kirtland's Warbler is highly dynamic, as known sites pass out of use within a few years and new potential sites are created through logging, prescribed fire, and wildfire. The population of the Kirtland's Warbler hovers around 400 individuals (based on field censuses of an estimated 200 males), and is highly dependent upon the available nesting area. An example of this sensitivity is the 1980 Mack Lake Fire in Oscoda County, Michigan, which destroyed nearly 25,000 acres of jack pine and mixed pine-hardwood forest. Warblers began nesting in the regenerating burn beginning in 1986, and the population of singing males within the county has doubled, from 80 in 1985 to 166 in 1990 (M. DeCapita, pers. comm.). Since the nesting habitat of the Kirtland's Warbler is constantly changing, an integration of remote sensing and GIS technology is attractive for management of this species. The objectives of this project were to identify all present potential nesting habitat for the warbler, and to evaluate the suitability of each potential site in terms of several landscape shape indices.

BACKGROUND

Mayfield (1960) and Walkinshaw (1983) have described the particular nesting needs of the Kirtland's Warbler in detail. Naturally-regenerated stands of young jack pine (8 - 21 years) growing on the Grayling Sand series of soil are favored by the warbler, with the young jack pine thickets providing shelter and concealment for the nests. Typically, warblers begin to occupy sites when the pine seedlings are 2-3 meters in height, and use declines sharply as tree height approaches 5-6 meters, and the branches closest to the ground die off. Consequently, the total area of potential habitat within this region is constantly changing as sites are created and site conditions change with age. Sites under 32 hectares are not commonly favored by the warbler (Mayfield (1960).

Since the warbler builds its nest on the ground, it is critical that the soil drain rapidly after a precipitation event. The Grayling soil provides favorable conditions for nestbuilding, with a thin to nonexistent humus layer, and perviousness extending to one or more meters below the surface (Oscoda County Soil Survey, 1931). Regeneration of jack pine occurs slowly on this poor soil, providing favorable conditions for the warbler for an extended period of time (Harwood, 1981). The soil occurs predominantly on former glacial outwash plains within the study region.

STUDY AREA

The study area for this research is located in Crawford and Oscoda Counties, Michigan (Figure 1). Jack pine and red pine (*Pinus resinosa*) are the principal lowland conifers, occupying former glacial outwash plains, while oaks (*Quercus spp.*), paper birch (*Betula papyrifera*), and aspen (*Populus tremuloides*) predominate in the uplands. Other tree species common to the region include tamarack (*Larix laricina*), black spruce (*Picea mariana*), and white cedar (*Thuja occidentalis*). Understory vegetation is typical of a northern pines forest, comprised primarily of blueberry (*Vaccinium spp.*), sedge (*Carex spp.*), and bracken (*Pteridium acquilinum*). Much of the forest in this region was logged and burned during the period 1880 - 1920 (Whitney, 1987) .

METHODOLOGY

Data Description

Thematic Mapper (TM) data acquired by Landsat 4 on October 27, 1982 (scene number 4010-15494) were chosen for assessment of potential warbler nesting habitat. The Landsat TM acquires spectral data in six reflective bands and one thermal band, with a spatial resolution of 30 meters in the reflective bands. The thermal band was not used in this study due to its low spatial resolution (120 meters) and poor contrast in forested areas (Horler and Ahern, 1986). Bands 1 and 2 (blue-green and green reflectance) exhibited a high degree of noise, and were also not used in this analysis. However, previous research has indicated that bands 3,4,5, and 7 provide the most information of the TM bands for forest cover mapping and analysis (Horler and Ahern, 1986; Leckie, 1990; Spanner et al.,1989). Ground reference information for this study includes detailed cover maps listing type, species, and density of the forest, produced by the

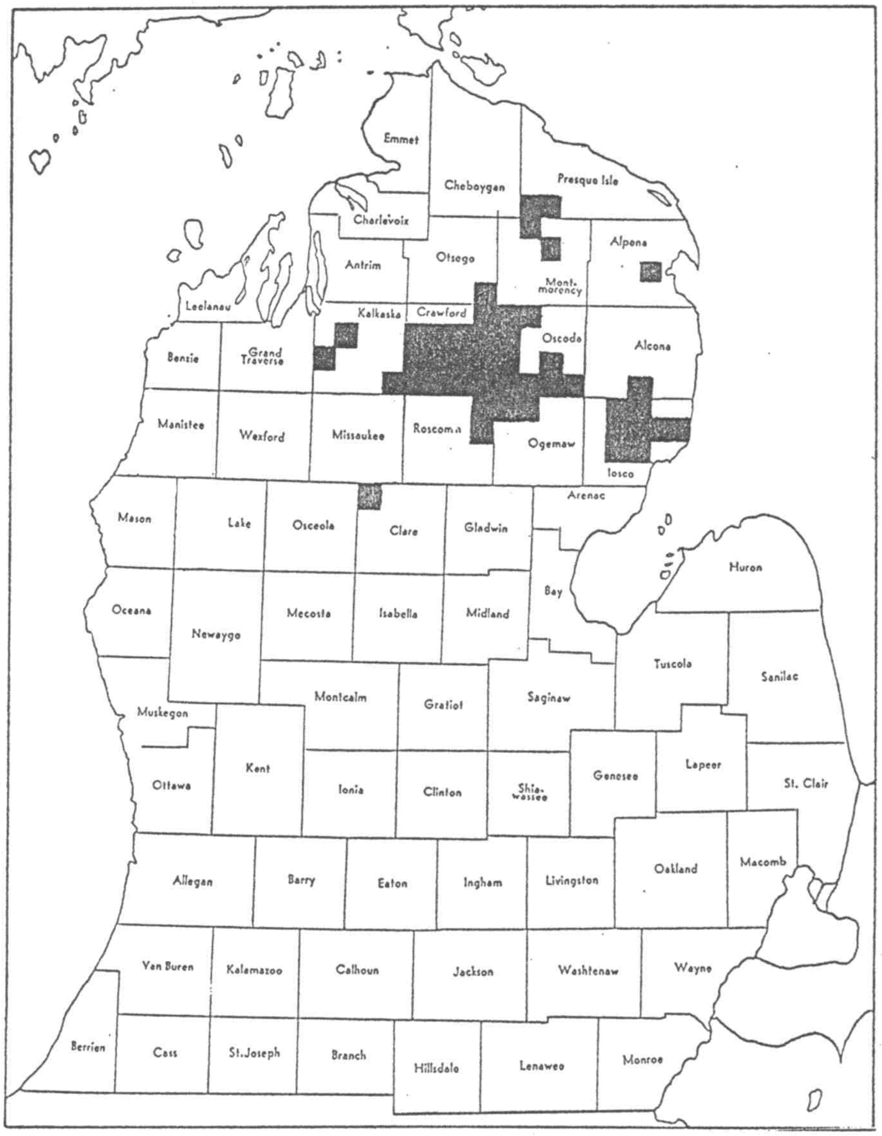

Fig. 1. Historic nesting range of the Kirtland's Warbler in northern lower Michigan during the 20th century.

Michigan Department of Natural Resources from black-and-white photography, 1983 and 1986 National High Altitude Photography (NHAP) color-infrared photography, and the Crawford and Oscoda County Soil Surveys (1931).

Data Analysis

A 20 by 30 kilometer area containing the study site was extracted from the TM scene and registered to a Universal Transverse Mercator (UTM) map projection using a set of ground control points and a cubic convolution resampling algorithm. Rectification of the data allowed coincident locations on maps, air photos, and the TM data set to be readily determined by UTM coordinates. Analysis of the Thematic Mapper data was performed using the ERDAS (Earth Resources Data Analysis System) software system. The TM data were masked prior to classification using a soils map digitized from the Crawford and Oscoda County soil surveys (1931). Since the Kirtland's Warbler has shown a preference for building nests on the Grayling Sand series of soils (Mayfield, 1960), all non-Grayling soils were assigned a value of zero, creating a binary map of Grayling/ non-Grayling soils. The soils map was registered to the same UTM projection as the Landsat data, and digitally overlaid on the rectified TM data to mask out data not coincident with the Grayling soil. Classification of the masked TM data was carried out using an unsupervised maximum likelihood algorithm, producing 30 preliminary spectral clusters.

To identify which of the thirty spectral classes represented nesting habitat utilized by the warbler in 1982-83, a modified chi-square test of independence was used (Lewis, 1984; Lowell and Astroth, 1989; Price et al., 1992). Confirmed nesting sites in 1982-83 (Probst and Hayes, 1987; Probst, 1986; Sykes et al., 1989; Walkinshaw, 1983), representing prime habitat conditions (stand ages ranging between 7 and 15 years, and open/dense regeneration) were digitized into the GIS, and a crosstabulation performed between known sites and spectral classes. A spectral class was defined as a habitat class if its observed frequency within known habitat sites was greater than would be expected from a random distribution of the class within the scene (Price et al., 1992).

From this test, it was determined that seven of the thirty classes were strongly associated with prime habitat conditions. These seven were combined into a single class representing prime potential habitat in 1982-83, and the remaining 23 classes were recoded into a non-habitat class. The preliminary habitat/non-habitat map was then converted from the raster ERDAS GIS format to Arc/Info vector GIS format for further analysis. Non-habitat "islands" less than 5 pixels (0.45 ha.) within habitat polygons were eliminated using the Arc/Info DISSOLVE command. Additionally, as the warbler prefers sites of at least 32.4 hectares in area, all habitat polygons smaller than 32.4 hectares were eliminated, producing 34 preliminary candidate sites.

Landscape analysis of sites

Mayfield (1960) observed that the warbler avoids linear or fragmented sites, describing one particular 2400 x 140 meter patch as ". . . suitable in all respects except breadth . . ." (Mayfield, 1960). Consequently, an effort was made to disqualify as prime habitat sites all polygons that were highly fragmented and without a "core" area meeting the minimum area requirement (32.4 hectares). Several techniques were explored to quantify the shape of the candidate habitat polygons and identify core areas of each polygon.

A simple shape index was calculated by dividing the perimeter of each polygon by its area (SI = P/A)(Lines and Harris, 1989). High values (0.020 - 0.028) were generated for complex, highly fragmented patches, and low values (0.007 - 0.012) were produced for fairly homogeneous, undissected patches. A shape index value for comparison was calculated for the site described by Mayfield (1960). A SI value of 0.015 was calculated for this comparison patch, and this value was used as an arbitrary maximum SI value for this study.

A disadvantage of the perimeter/area technique is that it is scale- and unit-dependent. To avoid this scale and unit dependence, a diversity index (Patton, 1975; Forman and Godron, 1986; Ripple et al., 1991) was calculated as follows:

$$DI = \frac{\text{Perimeter}}{2\sqrt{\pi \text{ Area}}}$$

The diversity index is a ratio between the perimeter of a polygon and the perimeter of a circle of the same area. For example, a DI value of 2.00 would indicate that the polygon had a perimeter twice that of a circle of the same area. The DI value is scale and unit-independent. A DI of 2.50 was calculated for Mayfield's patch described above, and for each patch in the preliminary sites map. DI values ranged between 7.71 (highly complex polygons) and 1.47 (nearly circular polygons).

The shape index and the diversity index presented certain disadvantages for the particular aims of this study. Although the SI and the DI both provide information on the complexity of a particular polygon, neither technique provides information on the specific configuration of a polygon, or the presence/absence of a "core area" within a polygon.

For example, SI and DI values calculated for a potential habitat polygon may range above the arbitrary maximums calculated from the site described by Mayfield (1960), but contain an undissected core area potentially suitable for warbler nesting sites. Additionally, two sites with essentially identical DI values may differ substantially in their value for nesting habitat (**Figure 2a**).

To overcome the limitations of the SI and DI, and to determine which sites contained core areas of at least 32.4 hectares, an alternative technique was employed using the SEARCH algorithm within the GIS. The SEARCH program was directed to search from the perimeter into each preliminary polygon 10 cells (300 meters), approximately equivalent to one-half the width of a square 32.4 hectares in area. Values of 10 or greater within a potential habitat polygon indicated that a minimum core area of 32.4 hectares existed within the polygon (**Figure 2b**).

Nine polygons of the original 34 contained sufficiently large core areas, and were output as the final potential nesting sites map (**Figure 3**). Similar results were generated for an landscape index created by dividing the area of a polygon by its diversity index (AI = A/DI), with a minimum cutoff value of 324000.00 square meters (32.4 hectares).

RESULTS

The potential nesting sites map was visually compared to maps generated by the U.S. Fish and Wildlife Service from field observations of warbler habitat in 1982-83. None of the 25 sites excluded on the basis of shape were occupied in 1983, reinforcing the assertion that the warbler prefers unfragmented sites with large amounts of interior. Two of the nine prime potential sites were definitely not occupied during the 1982-83 nesting period, while a third was occupied the following year. Another site was identified as a "warbler plantation", where the Michigan Department of Natural Resources had planted jack pines to establish nesting habitat. However, this area was not occupied during the 1983 season. The remaining five prime potential habitat sites (portions of three of these five sites were used in the class identification process) were

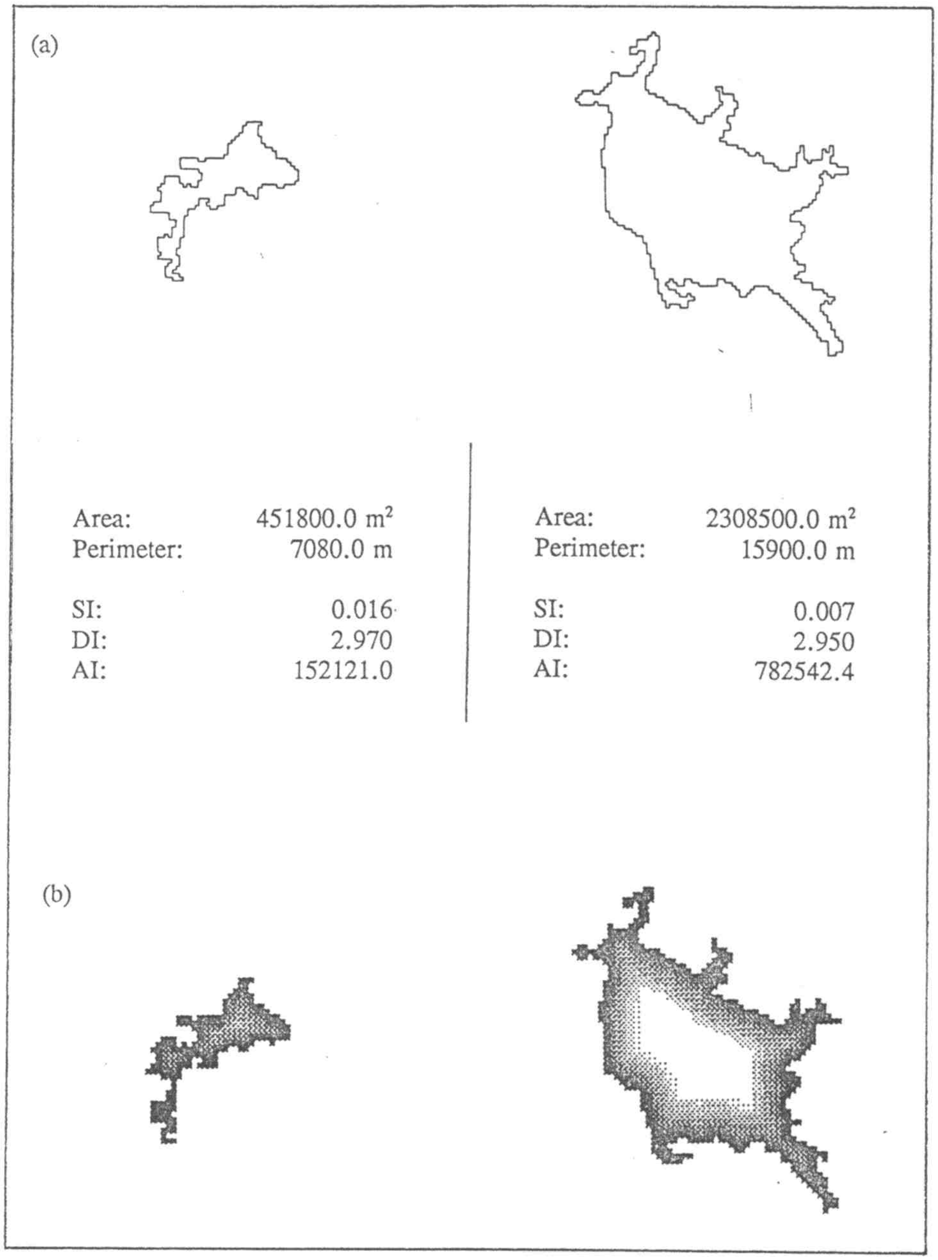

Fig. 2. (a) Comparison of shape indices for 2 potential nesting habitat polygons. Sample polygons have nearly identical DI values, but differ greatly in area and suitability. (b) SEARCH from polygon perimeter into polygon interior. White areas are 10 pixels (300 meters) or greater from the polygon perimeter, indicating a core area of at least 32.4 hectares.

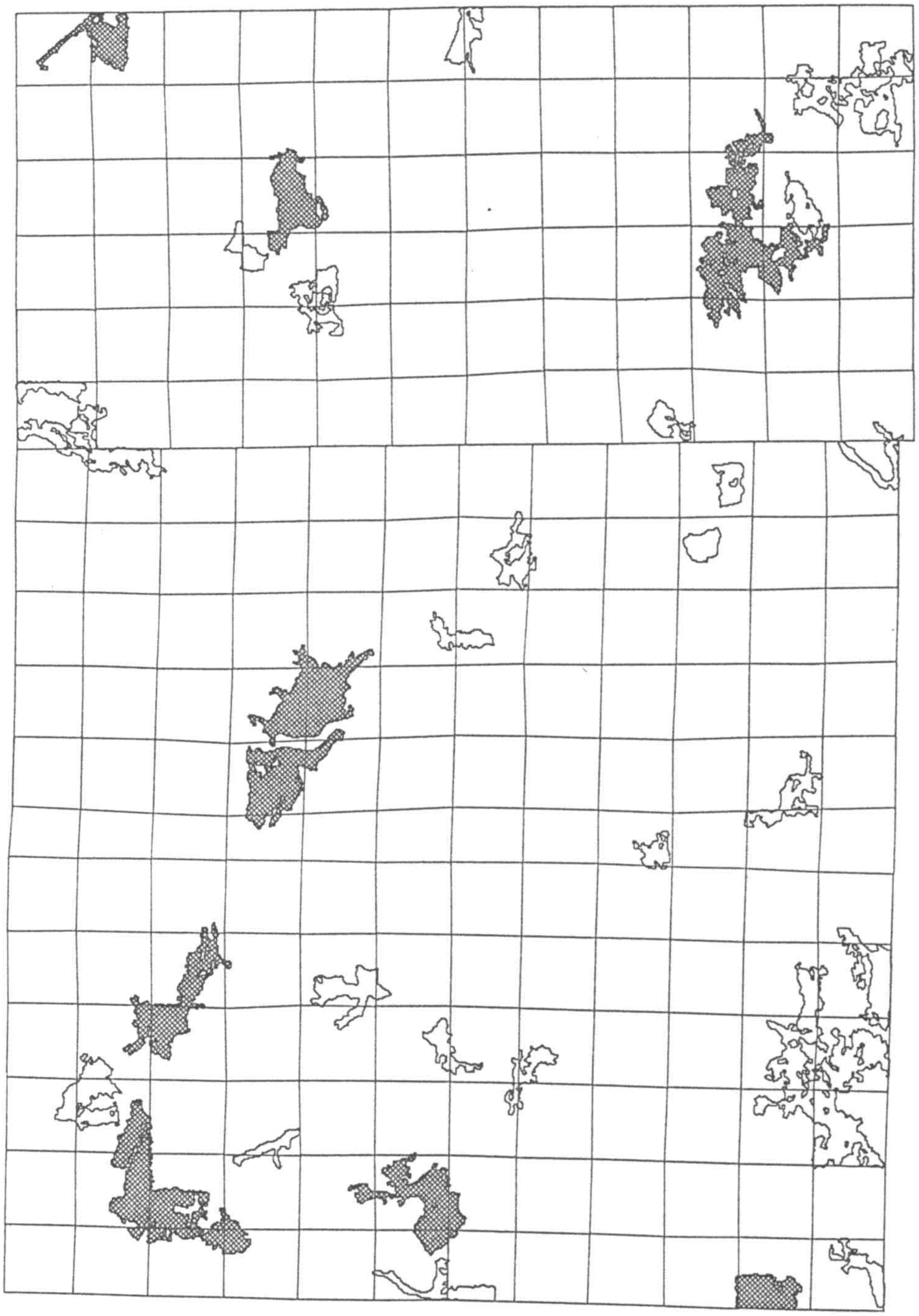

Fig. 3. Map of potential Kirtland's Warbler nesting habitat, Townships 26 and 27 North, Ranges 1 East, 1 West, and 2 West. Potential habitat polygons meeting shape requirements are shaded.

all occupied during the 1982-83 nesting season. Problems of habitat *overestimation* were attributed, in part, to insufficiently precise training sites, causing class # 30 to be included as a habitat class. Re-evaluation of this class with new field-derived information suggests that this class represents incipient habitat areas, i.e., clearcuts and recently planted plantations. Other field-verified nesting sites not identified by the integrated remote sensing/GIS technique were located on non-Grayling soils. This suggests some flexibility by the species in soil suitability for nesting sites, inaccuracy in the soils map itself, or both. The technique completely failed to identify an important site ("Muskrat Lake") occupied in 1982-83. Examination of TM imagery of this site indicates that the reflectance spectra of this site in all bands was not similar to other known habitat sites, grouping instead with mature forest classes.

CONCLUSIONS

While this research has demonstrated the ability of remote sensing/GIS technology to identify potential warbler nesting sites, field work is still necessitated for confirmation of site occupancy by the species. Field productivity may be maximized by narrowing the number of candidate sites and directing wildlife managers to sites with the highest potential for nests. A further advantage of this technology is that a multitemporal spatial database may be developed, permitting continuous monitoring of habitat over time. This study has also demonstrated the value in applying principles of landscape ecology to habitat management, eliminating sites which do not meet specified criteria for interior area and fragmentation.

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