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Landsat-Derived Land-Cover Classifications for Locating Potential Kestrel Nesting Habitat

Computer classification of Landsat data and a model for spatial analysis of land-cover types in nesting habitat were employed.

Introduction

The objective of the study was to test the utility of Landsat data for Kestrel habitat assessment of Sauvie Island, Oregon (Figure 1). To accomplish the objective, computer-generated land-cover classifications were used as variables in a habitat rating model and the model was used to rate the suitability of the study area, on a grid cell basis, for Kestrel nesting areas. To develop a model for rating habitat, a nesting area was defined in terms of cover types that were detectable from analysis of Landsat multispectral scanner data.

Abstract: *Nesting habitats of Kestrel falcons (*Falco sparverius*) were located using Landsat computer-classified data and a nesting habitat model. The model was based on a description of spatial characteristics of land-cover types important to nesting Kestrels. To evaluate this methodology and verify the model, model ratings were used to locate additional nesting areas. The additional areas were a separate set from those employed to develop the specific form and variable weights of the model. Census data revealed that seven of ten habitat cells (100 pixels) were actual nesting areas for Kestrels.*

By employing computer-classified Landsat data, the presence and spatial characteristics of important land-cover types were determined for nesting Kestrels. As categorized Landsat data forms a matrix or grid of vegetation communities, it is possible to measure areal extent, intersperion, and juxtaposition of these habitat types from the matrix. A Kestrel habitat quality model was developed by defining habitat needs of an indicator species in terms of computer categorized land-cover types and spatial arrangement.

Habitat quality, as the term is applied here, relates to the potential of a management unit to attract and maintain a population of nesting Kestrel falcons. However, it is not intended to convey a measure of actual number of the species or nests. The principle for enumerating habitat requirements is based on theories of habitat selection. Habitat selection is manifest in measurable terms, through species preference for zones in environmental gradients, as determined by a census. The measurable attributes (habitat components) can be derived from land-cover data that were derived from Landsat data.

The study area (10,938 hectares or 24,064 acres) is located on Sauvie Island in the Columbia River, three miles downstream from Portland, Oregon (Figure 1). A variety of land-cover types occur on the Island. Wetland, pasture, and agricultural areas are characteristic types, and the variety and interspersion of land-cover types provide many different habitats.

From a census of Kestrels on Sauvie Island, several land-cover types and their spatial characteristics were found to influence the location of Kestrel nesting areas. These included (1) the presence and relative abundance of land-cover types which

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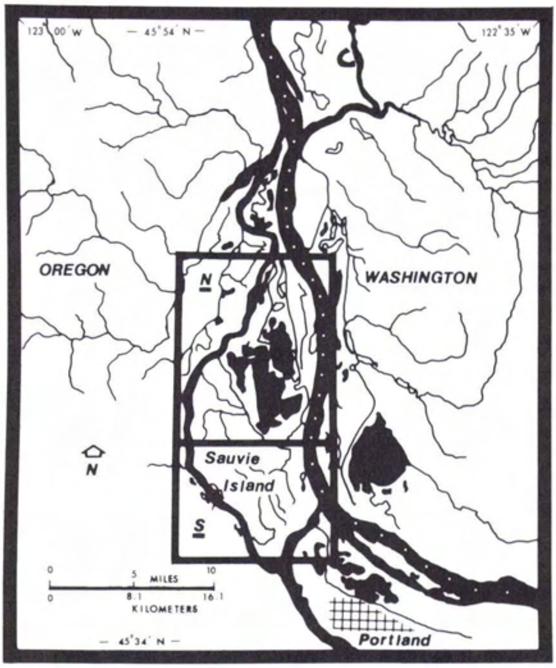

FIG. 1. Location of the Sauvie Island study area near Portland, Oregon. The Columbia River runs through the middle of the Figure, and the white dots indicate the Oregon and Washington border. The northern (N) and southern (S) portion of the study are enclosed by boxes. The northern area is presented in Figure 2.

supply food and cover for Kestrels, (2) the spatial distribution (interspersion) of these cover types in relation to the daily area of activity, and (3) the accessibility or juxtaposition of these cover types in relation to the daily area of activity. The habitat characteristics were employed in developing the variables of the model and weights of the contribution of variables to the model (Balgooyen, 1976). This procedure is similar to work done with deer and waterfowl habitat quality models (Roller, 1978; Roller and Colwell, 1978).

The model and specific contributions of each submodel were weighted and verified through several procedures: (A) field determination of Kestrel nesting habitat; (B) characterization of this habitat in terms of land-cover classifications from Landsat data; (C) selection of model parameters; (D) use of field information for determining the weights of contribution for each submodel to the model; (E) calculation of the Kestrel habitat quality ratings with land-cover inputs from Landsat classification; and (F) model verification with a separate data set containing examples of good and poor nesting habitat. These procedures are summarized in Table 1.

METHODOLOGY

The Computer land-cover classification was completed with Electromagnetic Systems Lab-

TABLE 1. DESCRIPTION OF ANALYSIS PROCEDURES USED IN THE STUDY OF KESTREL NESTING AREAS

Analysis Step	Number of Samples	Sample Unit	Purpose
A. Landsat training and digital classification	Entire study area (50,000 pixels)	Landsat pixels	Determine land-cover classes
B. Vegetation community (field) description	Subset of study area	Pixels	Determine cover of vegetation by canopy, shrub, and ground layer
C. Accuracy assessment	14 Primary sample units (PSU), 28 Secondary sample units (SSU)	PSU = 160 acres SSU = 9 pixels	Verify accuracy of classification of Landsat data
D. Kestrel field data collection	100 sightings	100-pixel block	Census of mated Kestrels and vegetation community description for each sighting
E. Habitat model development (model input data)	Entire study area	100-pixel block	Determine land-cover types found in Kestrel habitat
F. Verification and testing	Southern portion of study area	100-pixel grid	Training the model to discriminate nesting habitat
G. Locate potential or realized habitat	Northern portion of study area	100-pixel grid	Test the predictive capability of the model

oratory-IDIMS digital image processing system using a 25 July 1975 Landsat scene (2182-18204). Training areas were outlined on a color television monitor, and the data were processed with a clustering program (TSSELECT). Training statistics that were selected with this semi-supervised method provided better classification than those selected by supervised or unsupervised methods alone (Lyon, 1978).

Training statistics were evaluated using the DIVERGE and COMPARE programs. DIVERGE calculated the interclass separation of spectral clusters in the four-dimensional Euclidean space created by the Landsat channels (Swain and Davis, 1978). Separability was improved by combining spectral clusters with low values (below 1700 of a possible 2000). COMPARE allowed visual comparison of spectral clusters by displaying them on a two-dimensional plot of Landsat brightness values. Because clusters are identified by the clustering routine, they are (by definition) separate.

After completing these evaluations, the area was classified using preliminary training statistics. The accuracy of the preliminary classification was evaluated with U-2 color infrared photographs (NASA Missions 73-109 and 74-165) and field surveys. Final classification was made after training statistics were found to be distinct as judged with the subroutines COMPARE and DIVERGE, and to represent land-cover types within the area. A 50,000-pixel area including Sauvie Island was classified with a forty-cluster training set.

The accuracy of the final computer classification was evaluated with photointerpretation and field work. This was accomplished by randomly selecting fourteen quarter-section areas (primary sampling units) on two 1:24,000-scale quadrangles ($N = 28$) covering the study area. In each quarter-section image area, two secondary sampling units (SSU) of nine pixels each were selected. Each SSU was selected by using a grid with numbers, a random number generator, and a grey-level map overlay of the quadrangle. These SSU were examined and scored for classification accuracy by comparison with the vegetation description of the training set classes ($n = 252$, or a 0.5 percent sample of the 50,000 pixel scene). The size of the sample was determined by available funds and human power. The scene classification accuracy was 93 percent for the above subscene which includes Sauvie Island and was reported in Lyon (1978). The high accuracy resulted from a very good representation of the heterogeneous land-cover types found in the scene through use of forty clusters.

VEGETATION COMMUNITY DESCRIPTION

For each land-cover type, training set, or Kestrel nesting area, the vegetation was described through field work. In these descriptions, a modified form of the UNESCO-Fosberg method of vegetation mapping was employed (UNESCO, 1973; Mueller-Dombois and Ellenburg, 1974; Williams and Coiner, 1975; Lyon, 1978; Lyon and George, 1979). The UNESCO method characterizes land cover by the dominant plant types in each stratum or level of the vegetation. Cover is the vertical crown projection of important plants or land covers in a given pixel-sized ground area. This method can be used for plant species which make a significant contribution to the composition of the plant community (Lyon, 1978).

Vegetation cover descriptions were made for each land-cover type, training set, or Kestrel nesting area. For cover descriptions, a scale value was assigned to each stratum (canopy/shrub/ground). The scale consists of a cover estimate of 0 to 5 (0 percent to 100 percent cover) with integer values representing increments of 20 percent canopy cover. In Table 2, strata which are absent from the vegetation description are indicated by a "–".

KESTREL DATA COLLECTION

Kestrels were observed along a 64.3-kilometre road which circles the Sauvie Island study area. From the road, most interior areas of the Island could be visually scanned for Kestrels. No Kestrels were found in dense, wooded areas during the study, and all such areas could be examined from the road. Four observers participated in ten one-day sessions spaced at weekly intervals between February and April, 1977. Several variables were recorded during each observation of a Kestrel or pair: location, sex, behavior, and a description of land-cover types in a 100-pixel area around the Kestrel nest. Reliable determinations of sex and the presence of mated pairs were made because male and female Kestrels have distinctly different plumage colors and general body size.

To determine the land-cover composition of nesting areas, representative areas were selected from computer-classified data of the southern portion of study area (Figure 1) and were used to develop weights in the habitat model. The location of each observation of Kestrels pairs ($n = 41$ observations or 82 birds out of a total of 124 sighted in the entire study area, north and south) were transferred to a line printer map, and the land-cover types which compose nesting areas were enumerated from the computer classification. Using a 100-pixel grid cell overlay, ten cells ($n = 1000$, or approximately 2 percent sample of the Island) were selected from locations where Kestrel pairs were observed, and the land-cover classifications were counted within each 100-pixel grid cell surrounding the sites. The criteria for determining important land-cover classes for Kestrels was based on two measures of frequency. Land-cover classes with (1) a frequency of more than fifty in the 1000 pixels that were sampled, or (2) those appearing in more than 70 percent of model training areas, were determined to be land-cover

TABLE 2. LAND-COVER TYPES ASSOCIATED WITH KESTREL NESTING AREAS

Computer Classified Land-Cover Type	Classification		
	UNESCO System[1]	U.S.G.S. System[2]	Ti_{max}[3]
Old Agriculture	– / Willow[2] / grass[3]	21	0.20
Agriculture	– / – / grains[5]	21	0.10
Pasture	– / – / pasture grass[5]	21	0.20
Pasture	oak trees[1] / – / grass[4]	21	0.10
Old Field	– / small ash[2] / grass[3]	32	0.12
Wetland Meadow	trees[1] / – / sedges[4]	62	0.12
Water	– / – / water[5]	51	0.16

[1] Source: UNESCO, 1974. Superscripts refer to cover values in in percent (1 = 10%, 5 = 100%, in increments of 20% cover, "–" indicated an absence of cover in strata, canopy / shrub / ground).
[2] Source: Anderson *et al.*, 1976.
[3] Proportion of land cover in an optimal habitat (Ti_{max}) as determined by field work and analysis of literature, and as used in KMR.

classes commonly associated with nesting Kestrels. The criteria and sample size were dictated by the availability of sites where Kestrel pairs were observed in the southern portion of the study area. These land-cover types are presented in Table 2, and they were the same as those observed during the field portion of the study, i.e., wetland grasses, oak and ash trees in pastures, and fields.

HABITAT COMPONENT SUBMODELS

Habitat quality was evaluated on a per unit basis (habitat grid cell), in relation to the area of daily activity. Each habitat cell was the size of a Kestrel nesting area, or approximately 100 pixels (Balgooyen, 1976). Hence, model ratings were generated for each of the ten 100-pixel area of computer-classified map of the northern portion of the study area.

Three submodels constitute the model, which is presented in Table 3. The contribution of each submodel and its weight were determined from the relative presence of land-cover types and their spatial arrangement in nesting areas. The submodels are described below.

The Food and Cover (FC) submodel tabulated the relative abundance of land-cover types present in each 100-pixel cell. These quantities were compared with the optimal variety of cover types used by nesting Kestrels, as determined from a field census. The ratings compared the land-cover types with those of actual nesting cells. Weights for the contribution of each submodel were developed from data on composition of land-cover types.

Interspersion (INT) is the arrangement of land-cover types in a cell. An increase in cover types with a high ratio of edge-to-area results in greater interspersion (Roller and Colwell, 1978). This was related to simultaneous access to different cover types, and the species richness of vegetation found on the border between land-cover types (Roller, 1978).

The mathematical approximation to Juxtaposition (JUX) is the distance of edge multiplied by an edge desirability factor, which is divided by the total amount of edge in the unit. Edge was calculated by summing the perimeter of each group of pixels which compose each single land-cover type that forms a boundary with another cover type. This number was adjusted for shape to normalize the edge-to-area ratio of the cover types. The Edge number was normalized to the value of the perimeter of a circle, as it has the minimum perimeter per enclosed area. The edge desirability (Di) factor (Table 3b) related the relative quality of each combination of land-cover types that compose an edge. The Di weights were developed through field work and review of literature (Balgooyen, 1976; Roller, 1978).

The specific form of the model is presented in Table 3. The calculated values of food and cover, interspersion, and juxtaposition are presented in Table 4.

To evaluate this methodology and verify the model, model ratings were used to locate an additional ten 100-pixel areas in the northern portion of the study area (Figure 1), which have high model ratings and would be expected to have Kestrel nests. Model calculations were completed for each 100-pixel cell on Sauvie Island, using the Landsat-derived land-cover classification. Field determinations indicated that cells with a model rating above 20 exhibit a similar land-cover composition to nesting areas. Therefore, ten cells with model rating values above 20 were selected from the northern study area (Figure 2) to test the applicability of the model.

RESULTS

Census data revealed that seven of ten cells in the northern study area that were identified by the model proved to be actual nesting areas for Kestrels pairs. Seven of ten cells with model ratings above 20 were identified as nesting areas in the field (Table 4) by presence of nesting holes, feeding behavior, and other behaviors. In addition,

TABLE 3. THE KESTREL MODEL RATING (KMR). (A) GENERAL FORM OF THE MODEL AND WEIGHTS OF SUBMODELS. (B) EQUATIONS FOR THE SUBMODELS.

(A)

$$\text{KMR} = (\text{Cl}\cdot\text{FC})\,[(\text{C2}\cdot\text{INT}) + (\text{C3}\cdot\text{JUX})]$$

Where, KMR = Kestrel Model Rating
FC = Food and Cover Rating
INT = Interspersion of Cover Types
JUX = Juxtaposition of Cover Types
Cl, C2, C3 = Submodel Coefficients
(Cl = 160, C2 = 5, C3 = 5)

$$\text{KLM} = (160\cdot\text{FC})\cdot 5[\text{INT} + \text{JUX}]$$

(B)

$$\text{Food and Cover submodel (FC)} = \sum_{i=1}^{n} \frac{Ti\,/\,A}{Oi} \cdot Ti_{\max}$$

where Ti = area (in m^2) of cover type i.
A = area of the habitat unit under consideration (100 pixel area in m^2).
Oi = optimal relative abundance of a given cover type as determined by census.
n = number of cover types occurring in the habitat unit.
$Ti_{\max}$ = maximum proportion of optimal cover types in each cell, as determined by literature search and field work.

Interperion (INT) was calculated as follows:

$$\text{Shape Factor } (SF_i) = \sum_{j=1}^{m} \frac{\text{Edge}}{2\sqrt{\text{Area}_j\cdot\pi}},\quad \text{INT} = \frac{\sum_{i=1}^{n} SFi}{n}$$

Where Edge = the length of edge, in both X (57m) and Y (79m) directions.

Area = the area of the j^{th} polygon formed by groups of in the i^{th} cover class.

Juxtaposition (JUX) was calculated as follows:

$$\text{Juxtaposition (JUX)} = \frac{\sum_{i=1}^{n} \text{Di}\,(\text{JUX}_i)}{\text{JUX}_{\max}}$$

Where $\text{JUX}_{\max}$ = the average total weighted edge per habitat unit of good habitat, or 16319 for this case.

Di = the edge desirability weight for each cover type combination, based on census data, and review of literature.

JUX_i = the length of edge between combinations of cover types on either side of an edge.

TABLE 4. THE CALCULATED VALUES FOR THE FOOD AND COVER (FC), INTERSPERSION (INT), AND JUXTAPOSITION (JUX) SUBMODELS. THE KESTREL MODEL RATINGS (KMR) ARE INCLUDED.

Cell Number	Submodel Input Values			Overall KMR Rating	Nest Present
	FC	INT	JUX		
I	0.0103	10.2	0.8040	91	yes
II	0.0104	11.1	1.0000	100	yes
III	0.0062	4.7	0.2096	24	no
IV	0.0044	9.9	0.0663	35	no
V	0.0079	7.9	0.2171	51	yes
VI	0.0097	7.6	0.2809	61	yes
VII	0.0081	9.8	0.1849	65	yes
VIII	0.0096	8.5	0.1840	67	yes
IX	0.0106	6.8	0.4812	62	no
X	0.0119	7.7	0.4313	77	yes

CONCLUSIONS

The study evaluated a methodology for determining the suitability of an area as Kestrel nesting habitat. A model was used to evaluate presence and spatial arrangement of land-cover types within nesting areas. The presence of nesting Kestrels there was a general trend of higher total number of Kestrels (both male and female) with increasing values of the model rating, and Kestrels were found in nine of ten cells. The relationship of the number of Kestrels located in the cells to the Kestrel Model Ratings are presented in Figure 3.

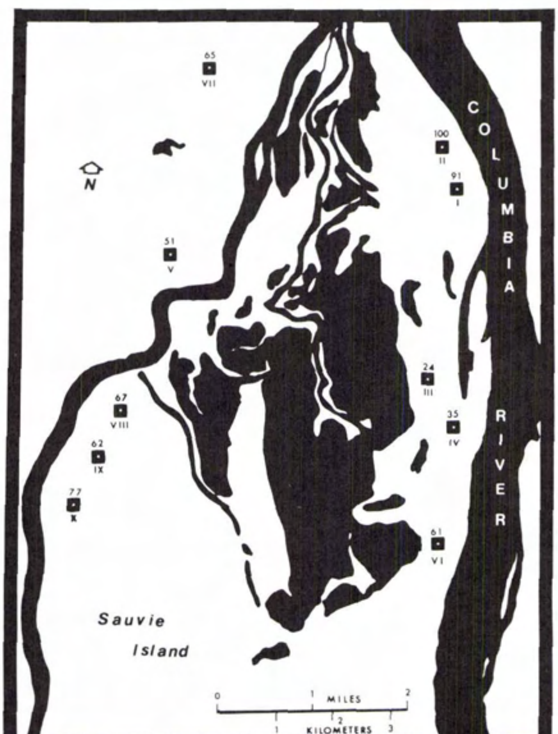

FIG. 2. Kestrel Model Ratings for the cells which were predicted to contain Kestrel nesting areas in the northern study area, and seven of ten cells had nesting pairs.

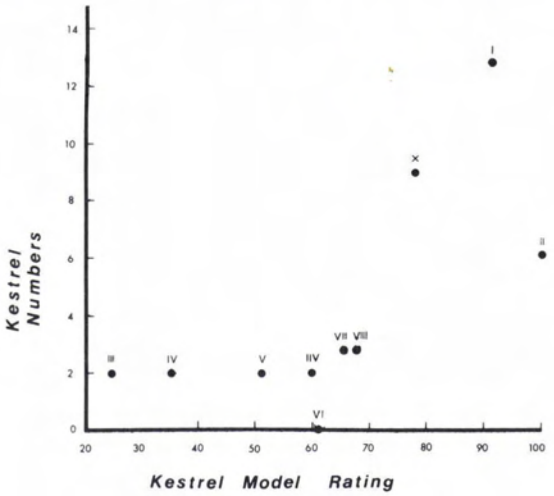

FIG. 3. A graph of Kestrel Model Ratings versus the number of individual Kestrels found in the areas.

was verified in seven of ten areas selected with model data. In addition, Kestrels were usually present in cells with model ratings above 20 (nine of ten areas).

The methodology is potentially applicable to Kestrel nesting habitat in other areas, provided the model can be developed and verified with Kestrel census and habitat data which are specific to the area. Several conditions are necessary to use the model and land-cover data for locating Kestrel or other animal habitats: (1) Model components must be quantifiable and have biological significance for the species to be studied; (2) the contribution of each submodel must represent the relative importance of each habitat characteristic for the species; (3) field data must be available to develop the weights of model components (train the model), and for verifying model sensitivity with the known characteristics of the species-preferred habitat; and (4) the land-cover types important to the species must be detectable from the remotely sensed data employed for the study.

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