Proceedings of the 19th International Symposium on Remote Sensing of Environment,
pp. 729-738. Ann Arbor, Michigan, 1985.

# USING LANDSAT TM IMAGERY AND SPATIAL MODELING IN AUTOMATIC HABITAT EVALUATION AND RELEASE SITE SELECTION FOR THE RUFFED GROUSE (GALLIFORMES: TETRAONIDAE)*

Jorge M. Palmeirim

Kansas Applied Remote Sensing Program,
and Museum of Natural History
University of Kansas, Lawrence, Kansas 66045, U.S.A.
and
Departamento de Zoologia, Faculdade de Ciencias
Universidade de Lisboa, 1200 Lisboa, Portugal

## ABSTRACT

Thematic Mapper (TM) imagery was integrated in a Geographic Information System (GIS) to develop automated models to evaluate and map ruffed grouse habitat, and select potential release sites for that species in northeastern Kansas (U.S.A.). Forest cover was mapped from a TM image using a mixed spectral/contextual approach. The high resolution of the TM imagery allowed a detailed mapping of forest edge, a critical element of potential grouse habitat in this region. Forest areas were then evaluated as potential ruffed grouse habitat by a spatial model using the following elements: (1) woodlot size, (2) woodlot interconnection, (3) amount of forest edge, (4) distance to woodlot edge, and (5) forest type. Another model generated a map of release site suitability based on the regional amount and quality of appropriate habitat. The results obtained were evaluated by wildlife management professionals familiar with the grouse and the local habitat conditions. It was concluded that the techniques employed have substantial potential as tools in grouse management.

## 1. INTRODUCTION

The low ground resolution of the Multispectral Scanner (MSS) (79x79m) has been a major factor limiting the use of its imagery in habitat studies. Nevertheless many papers have been published on the subject in the last few years showing a wide range of applications when a high ground resolution is not critical (for an overview see Palmeirim, in prep.). In particular the usefulness of MSS Landsat imagery in the selection of sites for reintroduction of locally extinct species has been demonstrated by various projects. Wild turkeys (*Meleagris gallopavo*) were released at sites selected using an MSS-based land cover classification (Katibah and Graves, 1978); monitoring the rates of conversion of rangeland to agricultural land using MSS imagery

*Presented at the Nineteenth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, October 21-25, 1985 assisted in the choice of release sites of pronghorn antelope (Antilocapra americana) in Kansas (Martinko, 1978). The higher resolution of the Thematic Mapper (TM) (30x30m) considerably increased the potential to use satellite-borne sensors in wildlife studies.

Most of the previous work focussed upon simple identification of habitat elements, such as vegetation. In spite of the usefulness of that work, it is unfortunate that so little effort has been expended in relating these elements to the actual needs or preferences of the individual animal species (but see Thompson, *et al*., 1980; Lyon, 1983). In this project I attempted to do this using TM imagery to generate a vegetation map, and GIS models based on the biology of the ruffed grouse (*Bonasa Umbellus*) were used to manipulate the vegetation map. An automated model was developed to evaluate the quality of the identified vegetation types as habitat for the ruffed grouse. This model generated a habitat suitability map which was then used in another model that selected potential sites for reintroduction of the grouse.

The ruffed grouse is a forest species with a wide range in North America. Due to its importance as a game bird various agencies have been reestablishing the grouse in areas where it became extinct in historical times, or even introducing it outside its historic range (Gullion, 1984). The Kansas Fish and Game Commission is currently attempting to restore this species in wooded areas in northeastern Kansas. Throughout most of its range the grouse depends heavily on aspen (*Populus tremuloides*, *P. grandidentata*) for food and cover (Gullion and Svoboda, 1972). However, in the southern part of its range, in the absence of aspen, the grouse seems to be mostly dependent on understory growth of shrubs, vines, and herbs for those requirements (Hale *et al*., 1982). Not surprisingly it is believed that in these regions it was, prior to settlement by Europeans and widespread extinctions, limited to ecotones and early successional areas (Hunyadi, 1984). Since Kansas is on the southern edge of the historical range of ruffed grouse these are the habitats where it is most likely to thrive in the state.

The study area is located around the intersection of Douglas, Leavenworth and Jefferson counties, just north of Lawrence, Kansas. It includes 52 $km^2$ (240x240 TM pixels) of intermixed rangeland, cropland, deciduous forest and old fields.

## 2. MATERIALS AND METHODS

Since many wildlife biologists have little knowledge of image processing methods, the objectives of the various operational methods carried out in this project are explained in general terms. A textbook on image processing (*e.g*. Schowengerdt, 1983) may be consulted for additional details regarding some of the techniques used.

All the image processing in this project was done on a Honeywell 66 DPS-3E computer. The photographic image products were generated using a Video Display Interface (VDI), installed on a Digital Equipment Corporation PDP-11/23, and a Terak 8510/23 Graphics Computer System.

### 2.1 SPECTRAL LAND COVER CLASSIFICATION

An automatic supervised spectral classification was first performed. The image was subdivided into various cover types, according to their spectral characteristics. A series of training areas of known cover was selected to characterize each cover type, and a set of training statistics was developed. These training areas were identified based both on the analysis of high altitude color infrared photographs (National High Altitude Photography Program), and on field checks. A total of 59 training areas were used to characterize seven information classes. After experimenting with various combinations, TM bands 2,3,4,5, and 7 were chosen. The TM image used was obtained by Landsat 4 on September 3, 1982. The spectral image classification was done using a modified version of the Kansas University Teaching

Image Processing System (KUTIPS) program package (Williams et al., 1983).

Two separate land cover maps were generated using the same training statistics but different classification algorithms. The Maximum Likelihood Classifier produced the map with the highest overall accuracy, but the Minimum Distance Classifier was more successful in mapping wooded areas. To take advantage of this situation the two forest classes of the Minimum Distance map were digitally overlayed onto the Maximum Likelihood image. The Map Analysis Package (MAP) (Tomlin, 1980) was used to merge the two classified images. The final land cover map used was therefore a combination of the results of both classifications.

### 2.2 CONTEXTUAL LAND COVER CLASSIFICATION

The contextual information in an image can be used to improve the accuracy of pixel identification (e.g. Gurney and Townshend, 1983). Contextual information was incorporated in the land cover classification following a simple and computationally inexpensive approach. Pixels that could not be assigned with acceptable certainty to any of the cover classes based on their spectral characteristics alone were submitted to the spatial classifier; each of these pixels was assigned to the majority cover in its immediate neighborhood.

Two approaches were used to spatially classify pixels, depending on the homogeneity of its neighborhood: (1) if at least five of the eight neighbors in a 3x3 pixel neighborhood of a particular pixel belonged to a single cover class the pixel was assigned to that class; (2) the identity of the remaining unclassified pixels was determined by a larger (5x5 pixel) neighborhood. However, since a pixel adjacent to an unclassified pixel provides a better clue to its identity than a pixel located further away, the individual contributions were proportional to the distance from the pixel being classified. This contextual classification was performed using a modified version of neighborhood functions available in the MAP package.

### 2.3 HABITAT AND RELEASE SITE EVALUATION

Extensive processing of the land cover map was needed to generate the habitat and release site maps. All the operations were performed using unmodified functions available in the MAP software. Although MAP is an interactive package, the large number of operations needed for each model made it advantageous to lay out sequences of commands in files; the commands were then executed automatically in the set sequence. This approach resulted in considerable time savings due to the need to make modifications in the models during their development. Implementing the same model in other areas and/or including minor modifications also becomes simpler and more accurate. Flowcharts and printouts of these command files are available from the author.

## 3. RESULTS AND DISCUSSION

### 3.1 LAND COVER CLASSIFICATION

The seven class land cover map generated included rangeland, old fields, standing crop, bare soil, water, and two types of deciduous forest. Since the ruffed grouse is a forest species I made a particular effort to optimize the mapping of these latter cover types. A comparison of the results obtained with aerial photography and field checks showed that the generated map (Fig. 1) accurately represents the distribution of forest in the study area. Small clumps of trees, the wider tree rows, and the intricate contours of the irregular woodlots characteristic of this area were evident. The gray area on the classified image (Fig. 1) indicates forest appearing younger, mostly on south-facing slopes, and black represents the remaining forest. The composition and structure of the forest on the south-facing slopes differs considerably from that of other exposures. This seems to be at least partially related to their age (Fitch and McGregor, 1956, include a description and history of some of the forest lots in the study area). The degree of confusion between the two types of forest on the classified map is hard to estimate, because no absolute criteria were established to separate them on the ground.

## 3.2 HABITAT EVALUATION

When visually classifying ruffed grouse habitat suitability using aerial photographs, the experienced wildlife biologist would make a series of more or less subjective decisions. The models used attempt to process the imagery making similar judgements. This is a particularly hard task because it is often not possible to state absolute rules for those judgements. In the following pages I will illustrate the various "decision steps" made, and explain their biological significance in the context of ruffed grouse habitat.

### Woodlot size and interconnection

The wooded areas were first isolated from the land cover map; other habitats were considered as not fulfilling the minimal ruffed grouse habitat requirements. The analysis will not be seriously affected if grouse use these habitats since this will only happen along forest edges. Although all forested areas can potentially be grouse habitat the high resolution of the TM imagery (30x30m) allows the mapping of very small clumps of trees, many of which are too small to be used by the grouse. Isolated forest pixels were therefore eliminated. Of the remaining woodlots some are still too small, unless they are located close to other woodlots. Forest patches separated from other forest patches by more than 300 meters were eliminated unless they had an area of 4 ha or more (Fig. 2). This area was chosen because one pair of grouse per 4 ha is about the highest possible density under most conditions (Gullion and Svoboda, 1972). Fig. 2 still includes some woodlots smaller than 4 ha; this is because they are close enough to other forest patches to be considered connected to them. This figure also shows that there is a high level of interconnection among the woodlots and that small patches of forest are important in the interconnection of the larger woodlots.

### Edge effects

The most important limitation of a habitat evaluation model based on Landsat imagery is that it can only include variables that can be directly detected and measured on the imagery or easily included as digital ancillary data. In the case of ruffed grouse habitat in Kansas, the inability of Landsat images to detect the structure of the forest understory is a serious limitation because in the southern part of its range the grouse seems to be mostly dependent on the understory (Hale et al., 1982). The imagery is, however, particularly suited for modeling using spatial components of the habitat and closely correlated variables. Forest edges are a good example - they can be accurately mapped and are closely associated with a denser understory. Overgrazing has destroyed much of the forest undergrowth in northeastern Kansas. This factor is likely to have been a major cause for the disappearance of the ruffed grouse in the state (Goss, 1891). Presently, dense undergrowth occurs mostly along edges, where growing conditions are more favorable and regeneration faster. Forest edges are therefore the most important single element in this habitat evaluation. TM imagery is well suited for this project because it allows an accurate mapping of the forested areas, and its comparatively high resolution portrays the detail of the woodlot edges. Using imagery with a poorer resolution, such as MSS, would result in a considerable loss of detail in these edges, which are so critical for the grouse. Forest clearings are often good habitat for the ruffed grouse in this area since they usually create an edge effect that generates a denser understory in the forest in their vicinity. However, very small clearings are probably not important habitat, and the likelihood that they are the result of a misclassification of the Landsat data is comparatively high. To avoid a major influence on the final habitat evaluation the smallest clearings were eliminated. Fig. 3 shows the results of this operation. The appropriateness of this step is however quite debatable because, while it eliminates undesirable image noise, it also causes the loss of some habitat information. Since the final result of the model was acceptable, this step was retained in the analysis.

Since forest edges are most likely the best habitat for the grouse in this area, the edge pixels were given the highest ratings on a scale of 0 (no habitat, lightest on Fig. 4) through 5 ("best" habitat, darkest on Fig. 4). In the map on Fig. 4 the relative quality of each pixel is proportional to its location in relation to the forest edge. Rating 5 was given to the actual edge pixels, 3 to pixels between 30 and 90 meters away from the edge, 2 to the pixels between 90 and 180 meters, and 1 to the innermost forest. Non-forest pixels were assigned a rating of 0. The scale is arbitrary and is designed to reflect relative probability of habitat quality: the probability of a pixel being suitable as habitat for the grouse is higher when located near an edge than in the innermost part of a woodlot. Further studies are needed to select an optimal rating scale.

Forest type

The preferred types of forest for the ruffed grouse seem to vary seasonally, even though grouse seem to use all types of hardwood forest (Bump, et al., 1947; Gudlin and Dimmick, 1984). Overall, the grouse seems to prefer second growth hardwood forest over climax forest, particularly for brood cover (Bump et al., 1947). Although preferences shown in other areas may not hold in the study area, the ratings of the areas of younger forest (Fig. 1) were increased slightly, by adding one unit to the previously assigned ratings (Fig. 5). The suitability scale now varied between 0 and 6, the highest value corresponding to second growth forest edge pixels.

Final habitat suitability map

Habitat suitability is better measured by an average of quality over an area than by the ratings assigned to individual pixels as in Fig. 5. The quality of each pixel as potential habitat for the grouse is not only a function of its characteristics but also of the forest pixels in its neighborhood. The rating of each pixel was, consequently, substituted by the average rating of the forest located within a circle of about 30 ha centered on the pixel (Fig. 6). Although the size of the scanning area is not critical, (because the technique is deriving a relative not absolute quality rating), the choice of 30 ha as the scanning area is based on the fact that this is a reasonable size for the home range of a male grouse (Gudlin and Dimmick, 1984; Woolf, et al., 1984). The cell ratings on this image can, thus, be considered a measure of the relative quality of home range of a bird that used the area within a circle of 30 ha centered on each cell. However, since nonforested pixels were excluded from these calculations, the actual averaged area may be much less than the 30 ha scanning circle. Notice on this figure that the highest ratings have been assigned to small and/or irregularly shaped woodlots due to the greater importance of edges in those lots. The lowest probability habitat suitability ratings were assigned to the innermost areas of the larger lots.

The road network was digitized and superimposed on the habitat suitability and following maps (Figs. 6, 7, 8, and 9) to make them easier to use. The signal of the roads on the original imagery was deleted to avoid confusion with the road overlay.

The suitability map on Fig. 6 is needed for the process of selection of release sites, but it can also have other applications in a grouse management project. For example, it can be used to help in the choice of sites to place man made drumming logs, since the areas with darker tones are more likely to become grouse territories.

## 3.3 RELEASE SITE SELECTION

Despite its usefulness the habitat suitability map generated (Fig. 6) still leaves open the question of where the release points should be located. One could select these points using the habitat suitability map by visually choosing areas including large amounts of good habitat. To locate the best candidate sites automatically the rating of each forest cell was made proportional to the amount and quality of the forest habitat within a circle having a diameter of 1800 meters centered on the pixel (Fig. 7). The choice of diameter is a compromise between the need to sample a considerable amount of habitat and the advantages of keeping a small scanning radius. The use of a larger radius could result in suggested release sites located far from patches of good habitat; the spatial correlation between the generated "release sites" map and the "habitat suitability" map is inversely proportional to the length of the radius used. The 1800 meter diameter was chosen to reflect known dispersion patterns of grouse away from release sites (Gudlin and Dimmick, 1984).

Before performing the scanning operation the values on the scanned map (Fig. 6) were squared. The squaring operation was designed to increase the relative contribution of the best habitat types in generating the "release sites" map (Fig. 7). The rating scale ranged then from 0 (lowest, no habitat) to 36 (highest, best habitat). The values of all the pixels within the scanned area were then averaged; the value obtained was assigned to the center pixel.

The "release sites" map is intended to be an aid in the location of sites to release grouse. The suitability of the areas having the highest ranks should be field checked first. Grouse can then be released either on these high ranking areas or in neighboring areas of good habitat (as suggested by the "habitat suitability" map and field checks).

In the choice of release sites there are usually two main considerations: (1) site quality, which was discussed above and is dependent on the habitat suitability around the potential site (Fig. 7), and (2) convenience, a component most often dependent on the accessibility of the site. A very good site may not be used because it is too costly to reach. In this study area the dense road network and the absence of common obstacles such as large water bodies and rough terrain make the access to all areas fairly easy. However I include here, as an example, a simple extension of the release site selection model that takes in consideration convenience.

The convenience of a release site decreases with the distance from a road. Since it is much easier to move in some land cover types than in others, it would not be appropriate to evaluate convenience with a simple distance measure; the difficulty of moving in the various cover types should also be included. I estimated that it is about three times harder to walk through the forest than through the other major cover types. Fig. 8 shows four levels of relative difficulty in reaching the various parts of the study area, taking into consideration the differences in mobility. Fig. 9 is a combination of Fig. 8 with the release sites map (Fig. 7); it combines the quality of release sites with their convenience. For sake of clarity only the higher ranking areas are shown in Fig. 7. The darkest tones represent very good quality and very good convenience (accessibility) ratings; the lighter tone also represents very good quality but lower convenience rating.

## 3.4 VALIDITY OF THE MODELS

A serious problem with the models presented here is the difficulty in testing their validity. Even if grouse are released and the species becomes established in the study area, it will take several years before its distribution and density will become a useful indication of habitat suitability. However, the experimental results obtained were evaluated by wildlife management professionals familiar with both the grouse and the local habitat conditions. It was concluded that the techniques employed have substantial potential as tools in grouse management. Field checks also support the utility of these TM imagery based models and they will soon be implemented operationally in a much larger area, which will help in their evaluation.

## 4. CONCLUSIONS

TM imagery proved to be appropriate for this project, in which accurate forest classification and detailed woodlot edge mapping were needed. The MAP package was an invaluable GIS tool. The many available general use commands when combined allow the implementation of complex image operations. MAP was used in this project not only to implement the models, but also to improve the spectral land cover classification, introducing contextual information in the final land cover map. The package also allowed the inclusion of roads as a reference system on the final maps generated. Various versions of the MAP package are now available, including one for microcomputers (pMAP, Spatial Information Systems) making this technology quite accessible.

The models implemented in this paper were designed to be used in northeastern Kansas. It was assumed that most good ruffed grouse habitat lies along the forest edges. The models are, therefore, applicable only where this assumption is met, as in the many areas lacking aspen along much of the southern range of the species. Model adjustments can be made to adapt the model to different areas. For example, the suitability rating of the non-edge forest, very low in this study area, can be increased if the model is applied to areas where the forest has a more dense understory.

This is one of the first attempts to combine Landsat imagery and spatial modeling in wildlife biology. However, the need for habitat models is great and many models based on habitat variables obtained in the field are now available (for the ruffed grouse see Cade and Sousa, 1985). These models have the advantage of basing their predictions on variables that describe habitat with more detail than TM imagery. The limited capability of satellite-borne sensors to provide information on certain important habitat components restricts the range of situations were the approach described in this paper can be successfully implemented. However, when applicable, models based on digital satellite imagery can be implemented quickly and inexpensively over large geographical areas. Because some of the variables employed (*e.g.* density of understory) are not directly detectable but are inferred from other variables (*e.g.* distance to edge), the various suitability maps generated in this project cannot be called absolute maps. The rating assigned to a pixel on these maps is intended to be correlated with the probability of that pixel being good habitat. The maps produced might therefore be better described as "probability" maps than "suitability" maps, as they are refered to for convenience in this paper. The results obtained support the belief that, when their limitations are not underestimated, these and similar models can be very useful tools in decision making for wildlife management.

## 5. ACKNOWLEDGEMENTS

I am grateful to Drs. R.S. Hoffmann, E. Martinko, J. Merchant, N. Slade, T.H.L. Williams and to S. Thorsteinsdottir for critically reading an earlier version of the manuscript. R. Rodgers and R. Wells generously shared their knowledge of the biology of the ruffed grouse. T. Chu provided valuable discussions and helped with programming. This research was supported by grants from NASA (NGL 17-004-024) and the Kansas Fish and Game Commission to the Kansas Applied Remote Sensing (KARS) Program.

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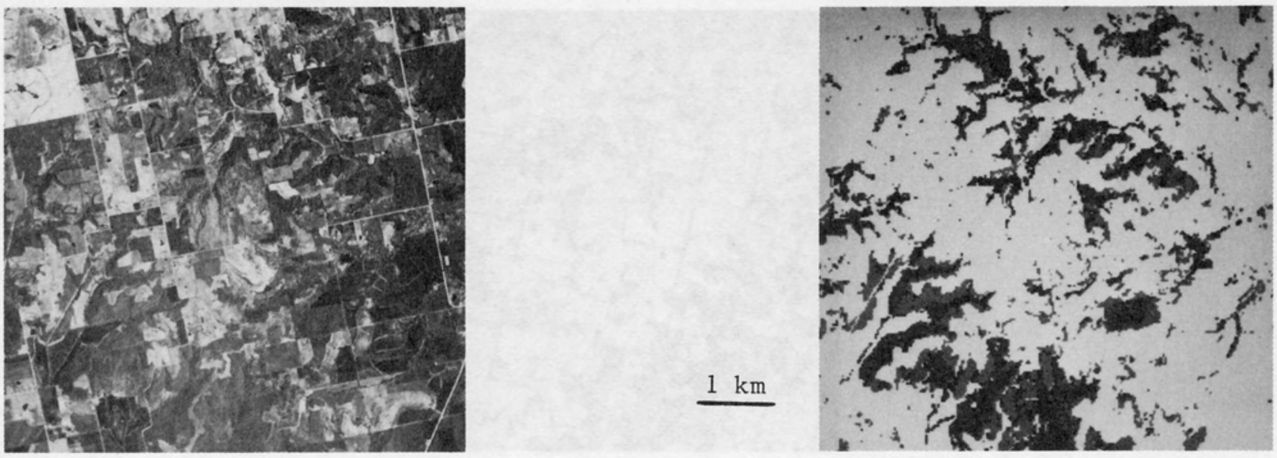


Fig. 1. (Left) IR aerial photo (NHAP) and (right) classified forest cover of study area. (On classified image gray is forest appearing younger, mostly on south-facing slopes; other forest is black.)

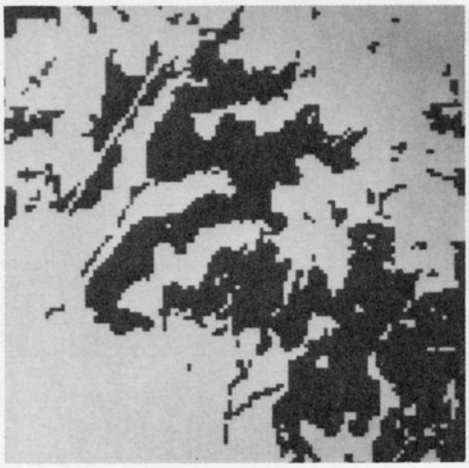

Fig. 2. Usable woodlots. (SW corner of study area. Single forest cells and small isolated woodlots were eliminated.)

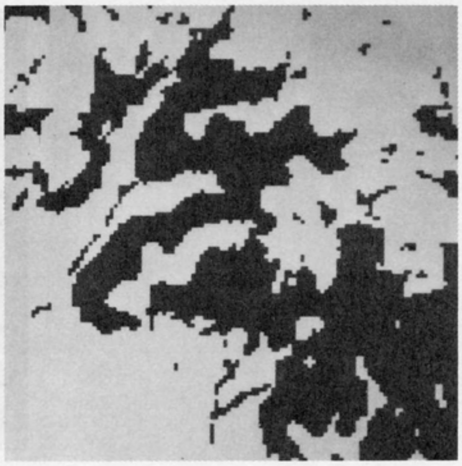

Fig. 3. Forest minus small clearings. (SW corner of study area.)

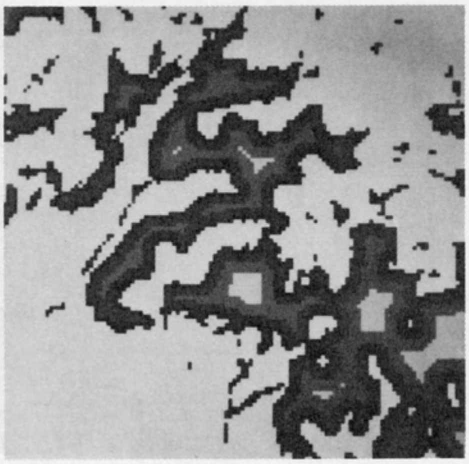

Fig. 4. Distance from edge. (SW corner of study area. Darker areas have a higher probability of being good habitat.)

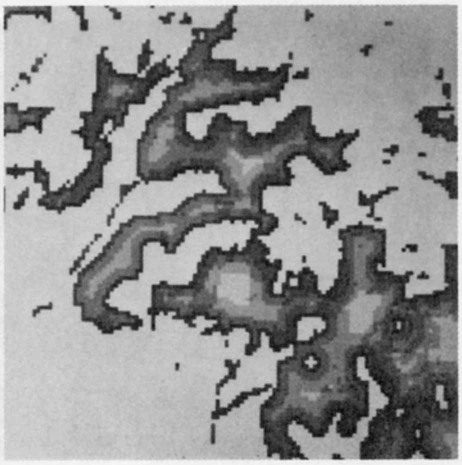

Fig. 5. Distance from edge and forest type. (SW corner of study area. Darker areas have a higher probability of being good habitat.)

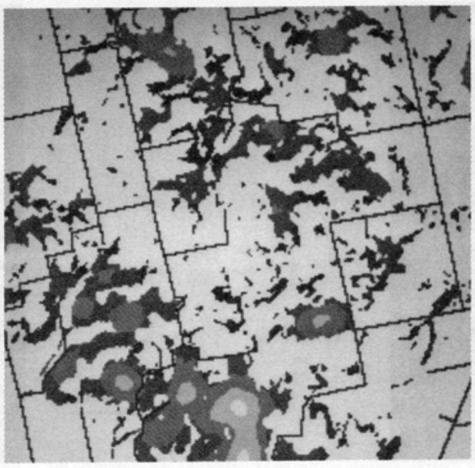

Fig. 6. Habitat suitability map.
(Darker areas have higher probability of being good habitat. Black are roads.)

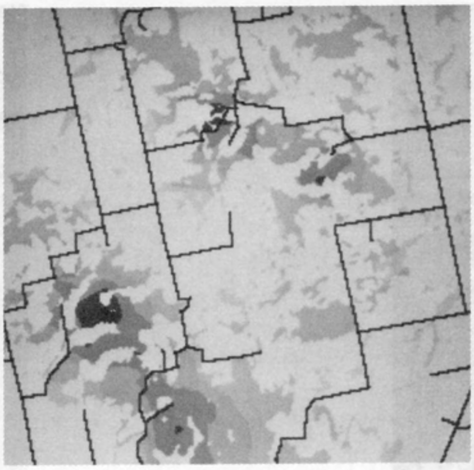

Fig. 7. Suggested release sites.
(Darker areas are more likely to be good release sites. Black are roads.)

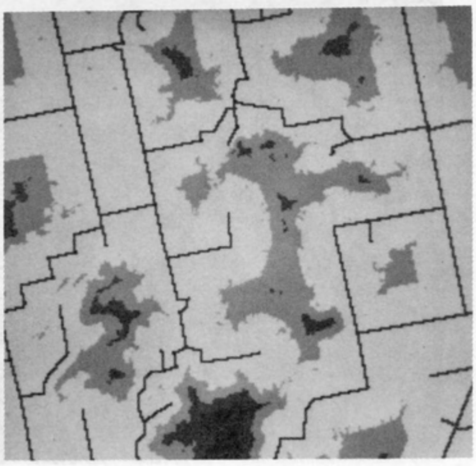

Fig. 8. Difficulty of access.
(Darker areas are harder to reach from roads. Roads are in black.)

Fig. 9. Good and accessible potential release sites.