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A Test of Habitat Evaluation Models Using Avian Densities

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A TEST OF HABITAT EVALUATION MODELS
USING AVIAN DENSITIES

by

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A THESIS

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A TEST OF HABITAT EVALUATION MODELS
USING AVIAN DENSITIES

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Habitat Evaluation Procedures (HEP) and the subsequent Habitat Suitability Index (HSI) models developed by the United States Fish and Wildlife Service are recognized as the foremost method available to natural resource managers for assessing the quality of habitat for wildlife. This technology, originally developed for aiding mitigation efforts associated with land development projects is now used in nonmitigation management decisions. This study analyzed the validity (ability to predict species abundance) of the models at this finer scale by comparing evaluation species densities with habitat evaluation results from a single management area.

Data were collected on the U.S. Army Corps of Engineers' Harlan County Project, in south central Nebraska. Evaluation models tested were the USFWS' HSI models for the eastern meadowlark (*Sturnella magna*), downy woodpecker (*Picoides pubescens*), and black-capped chickadee (*Parus atricapillus*), and an adapted grasshopper sparrow (*Ammodramus savannarum*) model from a Missouri Department of Conservation, USFWS, and US Soil Conservation Service model.

The HSI and HEP models were unsuccessful or only marginally successful in providing quantitative assessments of habitat

quality that correlated with estimates of evaluation species densities. Model HSI values correlated with downy woodpecker densities ($r = 0.74$). However, the species' habitat requirements and, consequently, the evaluation model were very simplistic. Black-capped chickadee densities correlated negatively with Food LRV ($r = -0.76$) and SI TWO (representing average height of overstory trees) ($r = -0.88$). Thus, the model incorrectly portrayed the chickadee/habitat relationships observed on the Harlan County Project. Tests of the meadowlark and grasshopper sparrow models failed to detect significant relationships between species densities and model results ($P > |r| = 0.3453$ and $P > |r| = 0.9107$, respectively). However, the meadowlark model included a relationship between average height of herbaceous canopy and meadowlark densities. Although no direct relationships were detected for the grasshopper sparrow, multivariate testing suggests that measurements of grassland conditions (litter depth, vegetative height, woody invasion, and forb cover) were indirectly linked with sparrow densities. Grasshopper sparrow densities tended to decline with retrogression of grasslands.

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INTRODUCTION

The Habitat Evaluation Procedures (HEP) were developed by the US Fish and Wildlife Service to rate the habitat quality of a tract proposed for development by a federal agency. However, soon after development of the methodologies, these procedures were adapted for other habitat management uses. HEP methodologies attempt to guide development of evaluation models that portray the relationship between an evaluation species and its habitat requirements.

The Fish and Wildlife Service's Habitat Suitability Index (HSI) Models, for regional application, were developed utilizing this approach to provide a standardized system of habitat evaluation. The HSI Models identify critical habitat conditions for an evaluation species and attempt to portray the relationship between habitat measurements, which represent the critical habitat conditions, and the quality of the habitat for the evaluation species. Suitability Index (SI) Graphs, based on available data, species expert opinions (when possible), and assumptions, graphically depict this relationship. The SI scale extends from 0.00, which indicates a habitat of no value to the evaluation species, to 1.00 which is indicative of optimal habitat quality for the evaluation species.

This standardized system provides several benefits supporting its usage. The concepts underlying HEP are intuitively appealing. Rating a tract of land in such a manner simplifies communication of the rationale of land management decisions to nonprofessionals.

Additionally, the models, which are widely accepted and applied by wildlife managers (Schamberger and Krohn 1982), generally, use repeatable, quantitative measurements employed by other natural resources managers such as foresters and range scientists.

One of the leading criticisms of the HEP approach to habitat assessment is the lack of corroborative data relating habitat suitability values with densities of the evaluation species. Therefore, this analysis was conducted to test the validity of these models in identifying critical habitat conditions necessary for an evaluation species, and in portraying the relationship among the measurements depicting habitat conditions and evaluation species' densities.

Validity of the models is not an absolute. Thus, varying degrees of success in interpreting the relationships between a species and its habitat were anticipated. The following study objectives were identified.

1) Test for a relationship between HSI values and evaluation species' densities.

2) Test for a direct relationship between species' densities and Life Requisite Values (LRV) and SI values generated by the model. This analysis determines whether any of the models' interpretive facets portray relationships between the habitat measurements and evaluation species densities. Failure of these tests indicates that the models may incorrectly interpret these relationships. Additional testing attempted to confirm that

habitat measurements recommended by the models were related to densities. Subsequent study objectives were identified.

3) Test for simplistic, direct relationships between habitat measurements and evaluation species' densities.

4) Plot habitat measurements with evaluation species' densities to determine if observed trends were contrary to predicted (by models) trends, or if undescribed nonlinear relationships existed.

5) Apply multivariate statistical techniques to identify potential indirect relationships among habitat measurements and evaluation species' densities, and to detect multivariate linear relationships among indices of habitat conditions and evaluation species' densities. Systematic adherence to these objectives was expected to indicate the success of the models in identifying correct habitat measurements, i.e. measurements related to evaluation species' densities, and in portraying the relationship between the habitat measurements and the evaluation species' density.

LITERATURE REVIEW

Habitat Evaluation Procedures

Many habitat evaluation systems have been developed in response to legislation over several decades (Baskett et al. 1980). Daniel and Lamaire (1974) provided a foundation upon which future evaluation models were developed. They promoted the unique concept that habitat should be evaluated for relative value to wildlife species instead of evaluation for monetary concerns.

Subsequently, many diverse evaluation methodologies were developed. Coinciding was the generation of characteristics that define an ideal evaluation system. Williams et al. (1977) identified three requirements an evaluation methodology must fulfill. First, the method must be easy to use and understandable for all potential users. The method must surpass classification by identifying courses of action and ecological consequences of those actions. Finally, the method should possess ecological integrity and simplicity, but remain effective.

Whitaker et al. (1978) identified 8 qualities systems should possess:

1) it must be able to assign a value figure for the habitat for individual wildlife species and groups of species by unit area,

2) these figures must display the effects of planned projects on the habitat so various alternatives can be compared,

3) the system must show effectiveness of mitigating proposals and the amount of compensation needed to offset

significant losses,

4) results must be acquired with equal accuracy by field personnel with varying degrees of experience,

5) it should give results that can be duplicated by different investigators at different seasons of the year,

6) the evaluation must be accomplished within the bounds of limited time and money,

7) the method should display the basis for all conclusions in a logical sequence,

8) the method should use information collected by specialists in other fields and generate data for use by others.

In response to the development of many evaluation methodologies and the identification of desired attributes, Schamberger and Krohn (1982) promoted the development and implementation of a standardized habitat evaluation method. Two primary benefits were expected from standardization:

1) improvement of communication within and among organizations and professions, and

2) provision of a framework around which species-habitat research can be founded.

HEP, first presented in 1976, was considered the most objective habitat evaluation technique available (Farmer 1977). The methodology incorporates elements from many other evaluation techniques. Parameters for evaluation of species, both game and nongame, are established within the system. Numerical values are attributed to specific criteria. Scores are derived through a variety of mathematical functions employed by specific models (USFWS 1980). These derived scores can be manipulated to facilitate comparisons of habitat quality both spatially and temporally, and to create quantitative estimates of habitat.

HEP begins with analysis for a single species' habitat requirements (Thomas 1982). Information such as the quality of habitat for a species or group of species are provided (Schamberger and Krohn 1982), which can be used to evaluate completed and/or prospective management programs.

Farmer (1977) identified 3 primary factors supporting usage of HEP:

1) HEP is a widely used and accepted method; it was the most widely used evaluation technique by the Division of Ecological Services of the Fish and Wildife Service in 1981 (Hardy 1981 by Schamberger and Krohn 1982),

2) HEP is a standardized method which conveys meaningful values to other researchers and managers, Schamberger and Krohn (1982) indicated that 1300 people nationwide participated in a training program,

3) the method is undergoing constant development. Regionalized data bases are being developed for 50 terrestrial species for each four-digit ecoregion described by Bailey (1976 by Schamberger and Farmer 1978). Coulombe (1978) described HEP as the most advanced activity in terms of problem identification, methodology development, testing, and implementation.

Despite widespread usage and acceptance, HEP has been subject to criticisms. Whitaker et al. (1978) indicated that as evaluation teams gain experince, comparisons between early work and more recent work declined in relevance. Furthermore, difficulty of displaying the basis for the values given each site so other biologists, professionals in other fields, and the public can understand them was a problem. Inability to replicate results, inaccurate assumptions, and the need for analytical improvements were viewed as shortcomings (Farmer 1977).

These comments were directed at early forms of HEP; the extensive further development and refinement of HEP ameliorated these concerns to a large degree. Following generation of the early forms (the Missouri Models) the Fish and Wildife Service presented a manual intended to provide guidance and standards for development of models or adaptation of existing models to be used in determining Habitat Suitability Indices (HSI's) (USFWS 1981). Additionally, many habitat evaluation models were developed and available for a variety of species. These more recent models, when combined with the Missouri Models (which are easily adaptable to more recent forms), provided a base of evaluation species with potential applications to the Harlan County Project.

Reviews of more recent forms of HEP generally indicated that HEP still failed to reflect habitat values accurately (Mulé 1982, Byrne 1982, Cole and Smith 1983). However, the methodology was frequently used for management projections and field situations

(USFWS 1982, Urich and Graham 1983, Rhodes et al. 1983, USFWS 1984).

Mulè (1982) found that testing of models for 7 species in Alaska yielded unacceptably low accuracy estimates of habitat quality when compared to species experts' ratings. However, the methodology effectively standardized estimates of habitat quality between teams to acceptably high levels of precision. Byrne (1982) found that most of the HEP models applied in the study failed to accurately predict limiting factors. However, the methodology was found more accurate than subjective evaluations. Thus, these Alaskan studies question the validity of HEP models.

Cole and Smith (1983), using HEP technology, developed models for 7 species at abandoned strip mines and tested their validity with population data. HEP was concluded as being unrefined, but receptive to improvements. Model development and validation were considered as top priorities in further refining HEP.

Since many models remain untested, Cole and Smith (1983) maintained that management decisions should not be based on the system. However, several examples revealed that HEP was employed in management programs. Urich and Graham (1983) used HEP to compare the benefits obtained from potential management programs. HEP was considered to be a logical planning procedure. Rhodes et al. (1983) found HEP beneficial in anticipating impacts of mine reclamation efforts and in identifying potential shortcomings in management efforts.

Studies have used HEP within the Republican River Valley near the Harlan County Project. The Nebraska-Bostwick Division Baseline Habitat Evaluation (USFWS 1984) employed HEP to determine baseline habitat conditions and develop mitigation recommendations. An evaluation using HEP was conducted for the Republican River Water Management Study (USFWS 1982) which included 11 evaluation species. The study examined existing wildlife resources and identified important problems and needs within the upper Republican River Basin.

In summary, the criticisms of Cole and Smith (1983) and Lancia et al. (1982) must be recognized. Additional validation is necessary. However, HEP, as a managment tool, is based upon the known natural history and habitat requirements of evaluation species. The models, based upon the information available, readily and easily serve to inform land managers of potential management needs. Though subtle differences of habitat quality can not yet be detected by HEP, general values of habitat quality which positively contribute to management, are derived.

STUDY AREA

The Harlan County Project is an Army Corps of Engineers management area composed of a reservoir and surrounding lands. The rolled earthfill dam was closed in July 1951, however, the multipurpose pool was not initially filled until June, 1957. The primary functions of the reservoir are flood-control and irrigation. Additional expected benefits include recreation opportunities, abatement of stream pollution, maintenance of a minimum streamflow, and flood control on the Kansas, Missouri, and Mississippi Rivers.

The Harlan County Dam is located in south central Nebraska on the Republican River, 361 km (236 mi) above its confluence with the Kansas River. The dam is approximately 3 km (2 mi) south of U.S. Highway 136 and Republican City, about 13 km (8 mi) east of Alma, 150 km (90 mi) southwest of Grand Island, and 308 km (185 mi) west-southwest of Lincoln. The total drainage area above the dam is 53,745 km^2 (20,751 square miles). The project area is approximately 5,385 ha (13,300 a) of reservoir and 6,883 ha (17,000 a) of terrestrial habitat. Total holdings accumulate to 12,250 ha (30,257 a) of fee and 481 ha (1,187 a) in easements.

A variety of habitats are provided on the area. Open grassland with scattered islands of woodlands, riparian forest, and croplands comprise the 3 predominant habitat types.

Harlan County is located within the Great Plains physiographic province. The county lies in the mixed grass prairie, a transition zone between shortgrass prairies to the west and the tallgrass prairies to the east. It is dissected by the Republican River which runs from the northwest to the southeast (Figure 1). The county is bisected north-south by U.S. Highway 183, and east-west by U.S. Highway 183.

Characteristic topography of the area is well defined stream channels with gently rolling uplands. Hills along the main valley vary from steep to moderately sloping. Drainage is almost entirely by the Republican River, Prairie Dog Creek, Sappa Creek, and their smaller tributaries. General slope of the county is from northwest to southeast.

Historically, Harlan County was largely grassland with woodland in riparian areas comprising a small percentage of vegetative cover. Now, virtually no area of Harlan County is untouched by humans. Approximately 2/3 of the county is cropland. Slightly less than 1/3 is utilized for grazing or hay production. Predominant crops in the county include wheat, grain sorghum, alfalfa, and corn.

Grassland type is largely determined by soil type, the water regime present at the site, and previous land use practices. Typical grassland species include big bluestem (scientific names in appendix B), little bluestem, switchgrass, downy brome, smooth brome, Kentucky bluegrass, buffalograss, small soapweed, mullein, and western ragweed.

Woodlands occur largely along waterways as riparian habitat. However, shelterbelts and windbreaks provide additional woody

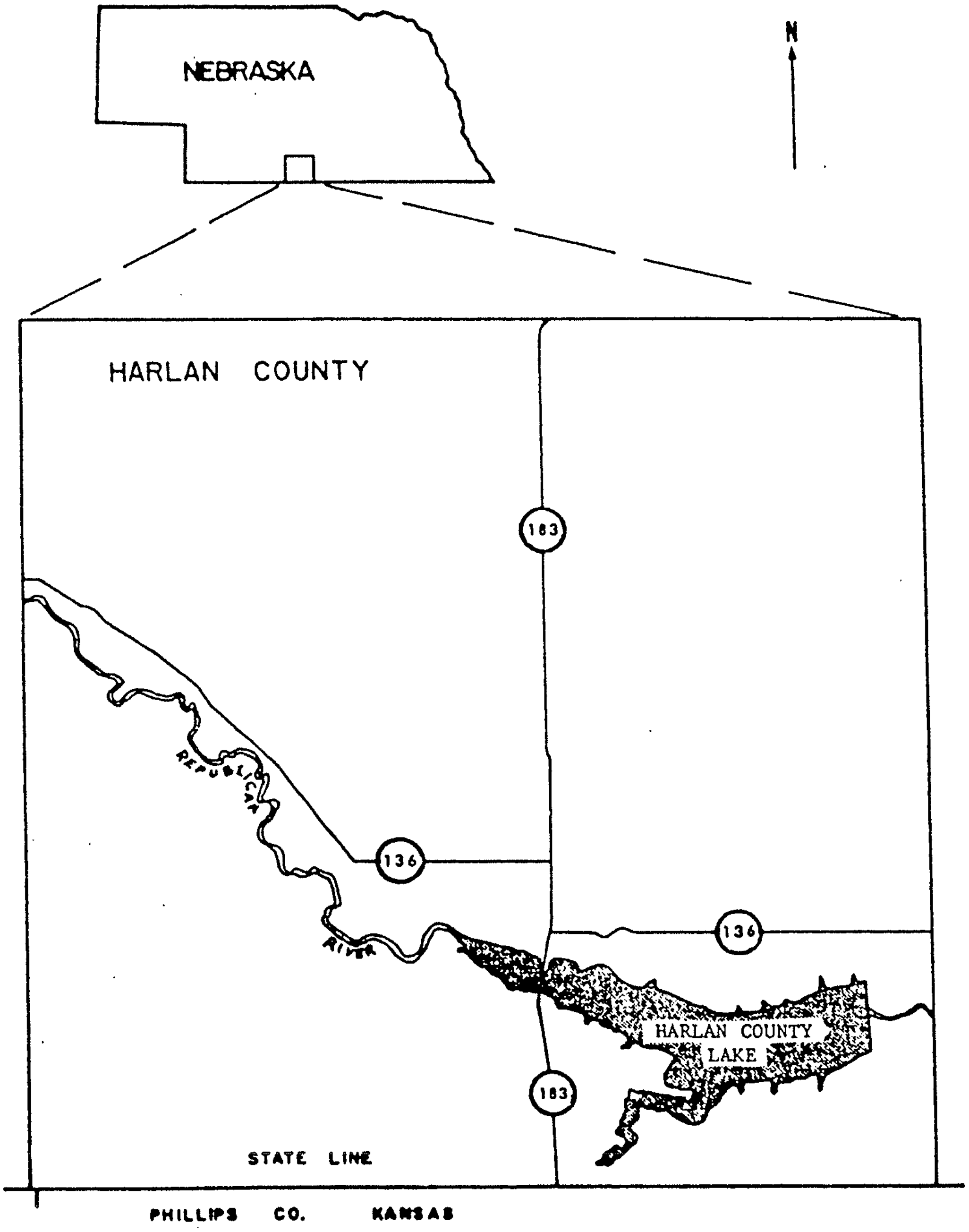


Figure 1. Location of Harlan County, Nebraska, and the Harlan County Project.

habitat. Typical woodland species include eastern cottonwood, green ash, box elder, red mulberry, American elm, and willow. Windbreaks feature these species as well as pines, eastern redcedar, hackberry, bur oak, black walnut, and others.

The area designated for study entails all lands held by the Army Corps of Engineers above the irrigation pool level (593 m [1946 ft]) or in the downstream flood plain. Three basic types of habitat were defined. Grassland habitats were areas composed largely of grasses and other nonwoody vegetation. Occasional strip plantings or drainages coursing through the grassland provided woody habitat. Comprehensive descriptions of the project's grasslands are available in Stubbendieck and Roberts (1984). Woody islands composed of trees and shrubs also occurred in these areas. Woodland sites larger than 2 ha with a width greater than 100 m were defined as forest habitat. Croplands habitat occurred where land was subjected to cultivation. Cropland areas were regularly broken up by grass strips and shelterbelts established in association with the natural resources plan.

Of the project's total terrestrial habitat, land under cultivation comprises 1,693 ha (4,181 a) or about 30% of available habitat, timber covers 1,240 ha (2,509 a) or approximately 18%, grassland accounts for 2,447 ha (6,044 a) or about 43%, wildlife plantings and other miscellaneous habitat types comprise 587 ha (1,451 a) or, roughly, 9% . The remaining terrestrial holdings are in public use areas (e.g. beaches, cabin rental units, campgrounds).

Grassland soils are typically of the Holdrege-Coly-Uly association (Mitchell et al. 1974). These are silty, loess deposited upland soils on divides and drainageways. Woodland and cultivated land generally occur on soils of either the Hord-Cozad-Hall association (silty soils of stream terraces and bottomlands) or the McCook-Munjor-Inavale association (loamy, bottomland soils). Generally, the soils throughout the area are fertile, but highly erodible.

The climate of Harlan county is typical of a mid-continental site. Summers are warm, and winters are relatively cold (Table 1). Annual precipitation averages 57 cm (22.3 inches). Generally, 80% of the annual precipitation occurs during April through September (Table 2). Peak precipitation usually occurs in early June.

Data were collected from 12 May to 18 August 1984. Spring temperatures were somewhat cooler than average. Temperatures for June, July, and August were close to average. March, April, and May were extremely wet months compared to average. However, June, July, and August were extremely dry months compared to average (NOAA 1983, 1984).

Table 1. Temperature (C) data for September, 1983, through August, 1984, and long term monthly averages (NOAA 1983, 1984), Harlan County Reservoir, Nebraska.

Month	1983 - 1984 Avg Max	Avg Min	Avg	Long Term Avg
September	28.4	10.8	19.6	18.4
October	18.8	5.8	12.3	12.1
November	9.6	-1.1	4.2	3.3
December	-7.4	-17.9	-12.7	-2.3
January	0.4	-10.8	-5.2	-5.4
February	8.2	-5.1	1.6	-1.9
March	7.0	-4.2	1.4	2.6
April	13.1	2.1	7.6	10.1
May	21.4	8.8	15.2	15.8
June	29.2	14.7	21.9	21.6
July	32.8	17.8	25.2	24.8
August	34.4	16.6	25.5	23.7

Table 2. Monthly precipitation (cm) data for September, 1983, through August, 1984, long term monthly averages, and number of days with greater than 0.25 cm (NOAA 1983, 1984), Harlan County Reservoir, Nebraska.

Month	1983-84	Long Term Avg	1983-84 Days (>0.25 cm)
September	15.0	6.2	4
October	2.3	3.3	3
November	3.7	1.5	4
December	1.3	0.9	2
January	0.6	0.7	1
February	2.7	1.3	1
March	7.1	3.0	5
April	13.3	5.1	8
May	10.3	8.6	9
June	6.9	10.0	9
July	1.0	8.3	1
August	2.0	7.3	2

METHODS

Habitat Evaluation Models

Selection of habitat evaluation models was completed prior to development of the sampling scheme and scale. Species selection for the habitat evaluations was based on several criteria. These criteria were:

1) the species should be a specialist so it reflects quality for a specific habitat,

2) the species must be present on the study area,

3) an available, accessible model and easily adaptable model must exist for the species,

4) the species model must require measurements that can be taken given time and equipment restraints.

Four models were selected because they successfully met the established criteria. The meadowlark and grasshopper sparrow models were selected to represent grassland habitats. Woodland areas were represented by 2 species: the downy woodpecker and black-capped chickadee.

The meadowlark is somewhat of a generalist compared to the grasshopper sparrow. The meadowlark may persist with success in early old field successional stages. Therefore, the meadowlark was not expected to respond significantly to moderate or subtle habitat differences. Contrarily, the grasshopper sparrow is sensitive to habitat variables such as woody growth and other variables reflecting a retrogressive grassland.

Upon completion of the species selection process, review, clarification, and modification of the models were necessary. Habitat Suitability Index models developed by the Fish and Wildlife Service for the black-capped chickadee, downy woodpecker, and meadowlark, were applied in unmodified form. These models were presented as being sufficiently documented, and of adequate regional generality to be appropriate "as is". Copies of the models as applied are provided in Appendix A. The grasshopper sparrow model required modification. A copy of the modified evaluation model is included in Appendix A.

The grasshopper sparrow model utilized was derived from a model presented by Urich et al. (1983). That model specified 8 variables; 7 variables were measured at Harlan County. The variable omitted, percent of field within 201 m (660 ft) of forest, woodlot, treeline, or shelterbelt, was excluded. It was difficult to clearly identify a field's limits (many grassland areas extended beyond project holdings without woodland borders) on the project. Also, the study's sampling design was inappropriate for collecting the data (sampling was at specific locations within a grassland tract). However, it was expected that the project would provide optimal values in virtually all areas. Variable curves were generated for 5 of the remaining 6 variables. The variable not having a curve (percent of vegetation within 5 cm of the average height of vegetation) was presented as a qualitative measure with only two discrete classes.

The 5 variables were average height of herbaceous vegetation, woody invasion, litter depth, forb foliar canopy cover, and herbaceous foliar canopy cover. Linear relationships were assumed to exist when ranges were provided for vegetative measurements and habitat values. Thus, suitability curves were made by graphing direct linear relationships between points. When a habitat measurement represented the maximum value of a lower suitability range and the minimum value of a higher suitability range, the plotting points were calculated by averaging. As an example, 70% herbaceous canopy cover was considered as the maximum of the 4 - 7 range and minimum of the 8-10 range. Accordingly, the value plotted for 70% herbaceous cover was determined to be 0.75. The overall HSI was then calculated by dividing the sample total by the total possible.

Avian Censuses

Methods selected differed between habitat types. The Line Transect Method (LTM) was selected for sampling habitat types that occurred in large continuous blocks. The Spot-Map Method (SMM) was chosen for areas of smaller habitat tracts containing particularly productive avian communities. Thus, grasslands were sampled using the LTM. Forested areas were censused using the SMM.

Selection of line transect locations was a 3-step process. The following steps led to selection of line transect sample sites:

1) random points were located within grasslands,

2) all possible azimuth readings that would allow a 1000 m

transect using the random point as the point of origin were defined,

3) a random azimuth reading was selected from the possible azimuths defined in 2).

In addition, line transect locations had to conform to three minimum requirements. These requirements were:

1) all transects were straight lines 1000 meters long,

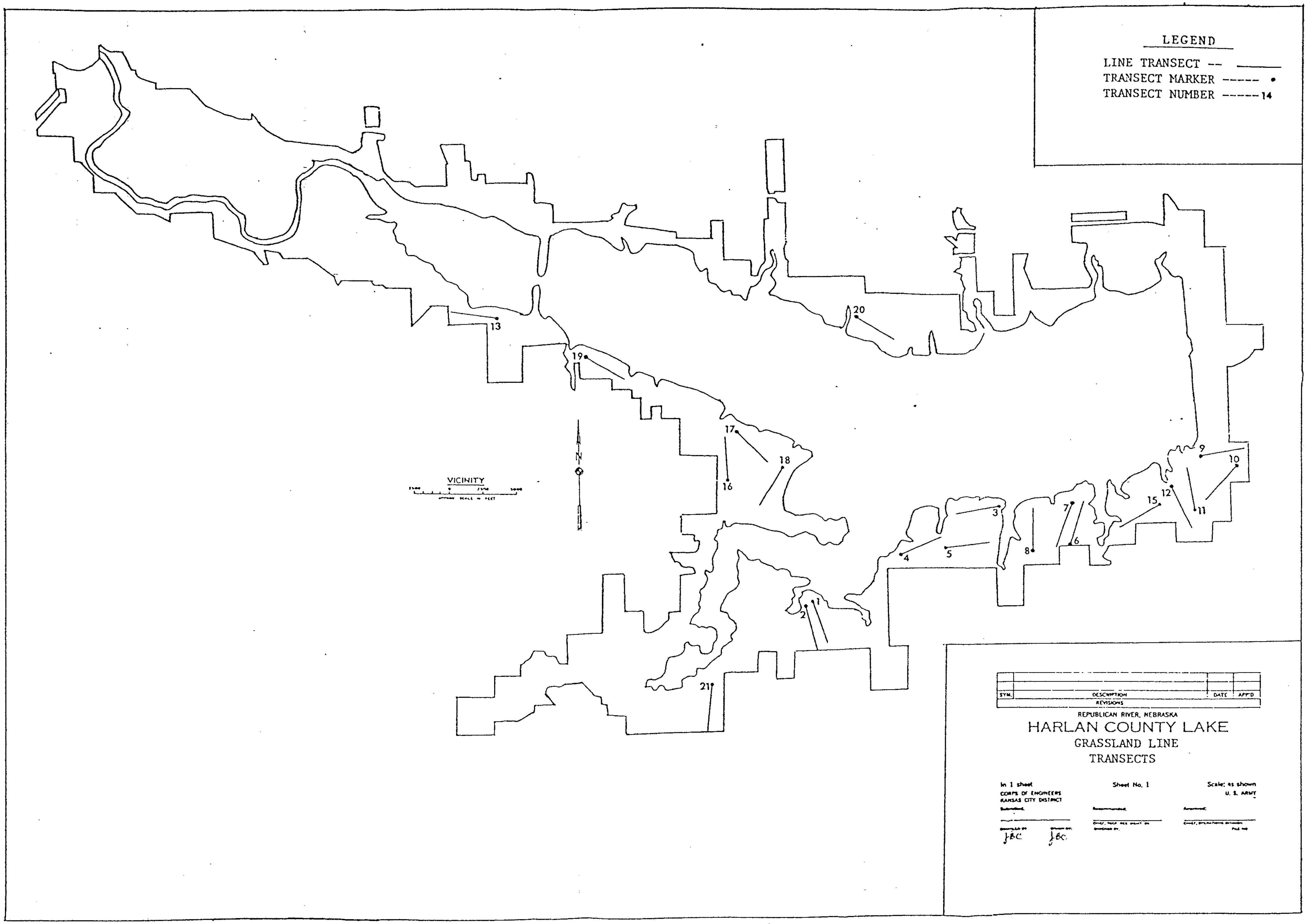
2) barriers that could seriously hamper observation of birds were avoided (e.g. sheer cliff faces, inundated lowlands),

3) transects oriented placed, if possible, at angles perpendicular to major habitat structures (e.g. habitat strips, fence lines) that could bias species composition and numbers.

Twenty-one transects were established and numbered (1 to 21). However, grassland transect 14 was abandoned before sampling began because effluents from the flooded Alma Municipal Waste Water Treatment Facility were pumped onto the site. Thus, 20 transects were sampled (Figure 2).

Transects were conducted following the recommendations of Emlen (1971, 1977) and Burnham et al. (1980). Observations were classified into belts of distance from the transect line. Belts identified were 0-10 m, 11-20 m, 21-30 m, 31-40 m, and 41-50 m. Too few birds were sighted in individual transects to permit usage of the TRANSECT program. The TRANSECT program, an alternative density calculation technique developed recently involving use of a computer program (Laake and Burnham 1980) based on "state-of-

Figure 2. Locations of grassland line transects, Harlan County Reservoir, Nebraska, 1984.


LEGEND
LINE TRANSECT --
TRANSECT MARKER -----
TRANSECT NUMBER -----14
VICINITY
N
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6
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3
4
5
1
2
21
SYM.
DESCRIPTION
DATE
APP'D
REVISIONS
REPUBLICAN RIVER, NEBRASKA
HARLAN COUNTY LAKE
GRASSLAND LINE
TRANSECTS
In 1 sheet
Sheet No. 1
Scale: as shown
CORPS OF ENGINEERS
KANSAS CITY DISTRICT
U. S. ARMY
JBC
JBC

the-art" transect evaluation methodologies (Burnham et al. 1980), require a minimum of approximately 40 observations to provide reliable estimates. However, in an effort to relate species densities on the Harlan County Project to other surveys, data from all 21 transects were grouped to permit usage of the program. However, validation of the HEP Models was completed using the total number of the individual birds observed on the transect as an index of density. This probably was less accurate than absolute densityestimates on the transects, but these indices were expected to remain comparable between transects.

Woodland plot sites were determined by selecting random points within forested areas. Each random point identified a corner for a spot-map plot. Constraints on woodland plot sites were:

1) woodland plots must be $\geq$ 2 ha but $\leq$ 10 ha,

2) plots must be square or rectangular shaped (to facilitate mapping and orientation within a site). The distribution of woodlands and high water, which prevented use of many woodland areas, concentrated acceptable woodland areas in only a few locations along watercourses.

Nine woodland plots were established (Figure 3 and Table 3); a lettering system (A through I) was used to identify each of the plots. Five plots, A, B, C, D, and I, were located west of Highway 183 on the reservoir's upper end. Four plots, E through H, were located at the project's east end near the dam. Dimensions of the plots varied by the amount of the woodland that

Figure 3. Locations of woodland study plots, Harlan County Reservoir, Nebraska, 1984.

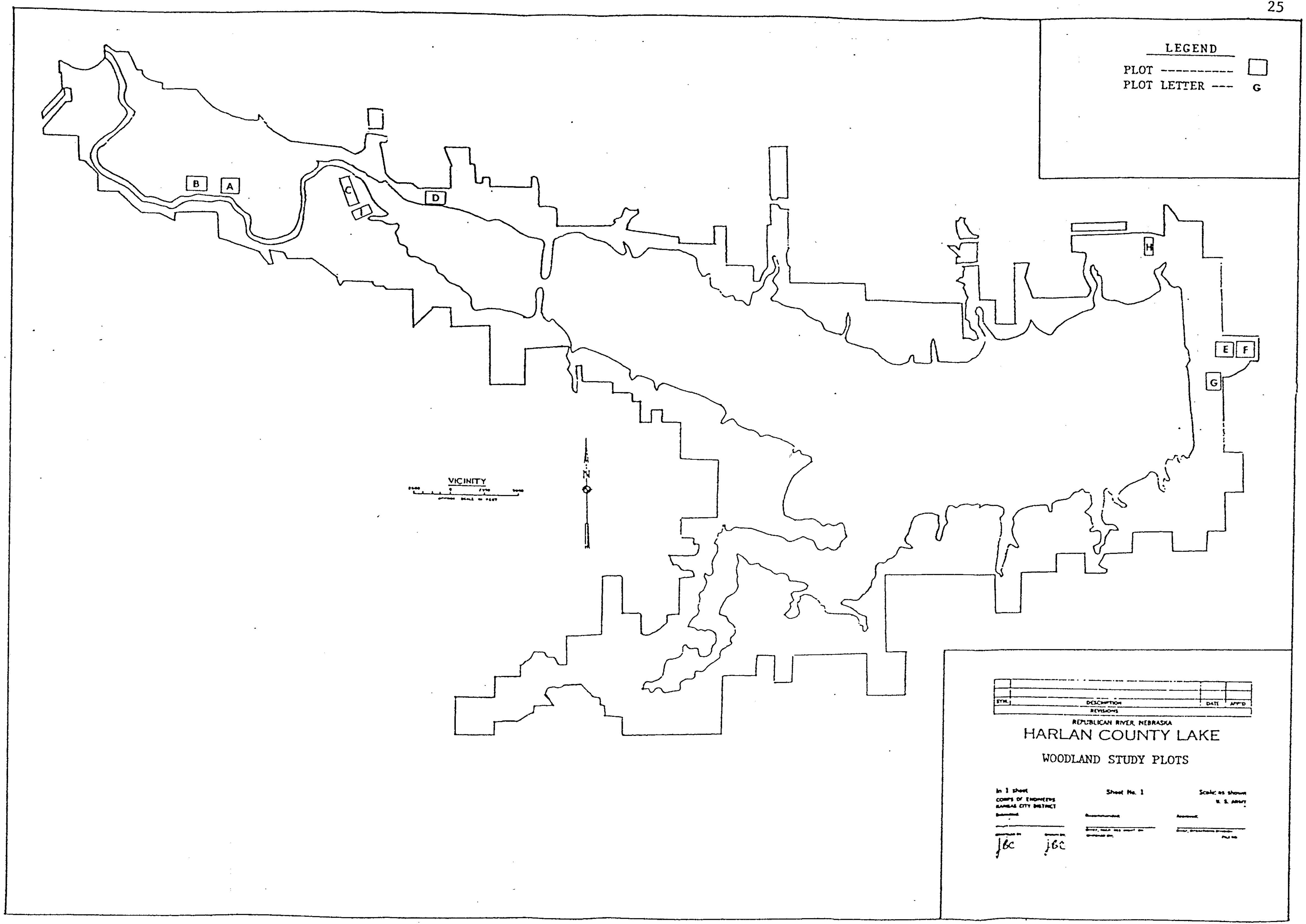
LEGEND
PLOT ----------- ☐
PLOT LETTER --- G
B
A
C
D
H
E
F
G
VICINITY
N
SYM.
DESCRIPTION
DATE
APP'D
REVISIONS
REPUBLICAN RIVER, NEBRASKA
HARLAN COUNTY LAKE
WOODLAND STUDY PLOTS
In 1 sheet
CORPS OF ENGINEERS
KANSAS CITY DISTRICT
Sheet No. 1
Scale as shown
U. S. ARMY
jbc
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Table 3. The dimensions and areas of woodland plots sampled for 1984 validation tests of HEP models, Harlan County Reservoir, Nebraska.

Plot	Length (m)	Width (m)	Area (ha)
A	320	250	8.0
B	320	250	8.0
C	500	150	7.5
D	300	200	6.0
E	320	250	8.0
F	320	250	8.0
G	320	250	8.0
H	300	200	6.0
I	300	150	4.5
Total	---	---	64.0

was accessible at each location.

Each woodland plot was censused following standardized methodologies (Anonymous 1970). All birds encountered aurally or visually on each census were located and recorded on the map. Single species maps for each plot were made by summarizing census data. Completed species maps were analyzed and the number of territorial males on the plot was calculated. Territories crossing the plot edge were recorded as one-half territories. The number of territorial males observed was multiplied by two to calculate species densities for each plot. Densities per plot were converted to densities per 40 ha to allow comparison between plots.

Vegetation Sampling

Grasslands

Grassland data were collected between 15 May 1984 and 27 June 1984; the grasshopper sparrow model required completion of sampling prior to July 1. Sampling was conducted along the line transect course. Within each 1000 m transect, 3 of a possible 10 100 m sample strips were randomly located. Each sample strip had 10 sample stations located at 10 m intervals (sample strip locations: 5 m, 15 m, 25 m, ..., 95 m). Habitat sampling was completed along the sample strip and at the stations located on the transect. Each sample strip provided a complete habitat evaluation providing HSI values.

The following measurements were obtained at the 10 sample stations along the sample strip:

1) distance to perch,
2) distance to water,
3) average height of herbaceous vegetation canopy,
4) height diversity of the herbaceous vegetation canopy,
5) litter depth,
6) herbaceous canopy cover,
7) forb canopy cover,
8) proportion of canopy that is grass.

Data collected at the stations were combined and averaged within sample strips.

Distance measurements were obtained in several ways. Distance to perch site was determined using a rangefinder, or measuring wheel. Potential perch sites were easily detected and distances measured due to the relatively high density and widespread occurrence of mullein and other tall, erect forbs. When water sources were nearby above methodologies were useful as well. However, when distances to water exceeded roughly 200 m, aerial photographs (1320 : 1 scale) were utilized. An engineer's scale was employed to locate transects, and strips, and stations within the transect.

Vegetation height and litter depth were measured twice at each station. A meter stick with a tapered lower end was placed perpendicular to the ground at arms-length, either side of the transect. Appropriate data were recorded (e.g. litter depth, herbaceous vegetation height). Vegetative height diversity was calculated by averaging vegetative heights and determining how many plants were outside the height range identified by the model (> or < 5 cm of mean vegetative height).

Herbaceous canopy cover, forb canopy, and the proportion of the canopy that was grass was determined using the Focal Point Technique (Burzlaff 1966). This technique employs a surveyors transit adjusted to focus at ground level. Ten points were sampled at each of the 10 stations. Data recorded were total vegetative hits, hits of forb vegetation, and hits on grass.

Woody invasion was measured using circular quadrats. Each quadrat had a radius of 4 m, thus providing a sample area of approximately 50 m^2. Each tree and each clump of woody shrubs was counted as one occurrence of a woody invader.

Percent shrub crown cover was calculated using the line intercept method (Hays et al. 1981). The entire 100 m length of the sample strip was measured.

Woodlands

Data were collected from 2 July 1984 to 2 August 1984 in woodland plots for the black-capped chickadee, and downy woodpecker. Sample strips 140 m long (Bormann 1953) were used within the SMM plots. Each sample strip had 10 sample stations located at equidistant 14 m intervals. Sample strips were randomly located along the census routes with 2 exceptions. Woodland plots B and H contained a systematic bias. The plots were predominantly open with discrete strips of woody cover running parallel to census routes. Thus, sample strips were oriented to run perpendicular to the woody strips (Bormann 1953) to avoid biasing data. The sample strip origin point was randomly located within the woodland plot.

Data were collected at each station, along a sample strip, and through a strip quadrat. Sample stations provided data for basal cover, and percent tree canopy closure (% canopy cover). A strip quadrat was used to determine average height of overstory trees (canopy height), and snag densities.

Station sampling was conducted in the following manner. Basal cover was calculated using a cruising prism with a Base Area Factor (BAF) of 4 m^2/ha plant (Hays et al. 1981). Canopy cover was determined using a spherical densiometer (available from Paul E. Lemmon, Forest Densiometers, 2413 N. Kenmore St., Arlington, VA 22207).

Strip quadrats, 140 m long and 4 m wide (Bormann 1953), were employed for sampling snag densities and average overstory height. Height of all overstory trees contained within the transect was determined with a clinometer.

Following completion of data collection for all species models, Life Requisite Values (LRV) and HSI's were generated. LRV's were determined, when appropriate, by the simple application of data to the model. HSI's were calculated by two methods. Method I entailed calculation of an HSI for each evaluation site. Averaging these HSI's provided an average HSI value and standard deviation (estimate of variation) for the area. Method II involved averaging of LRV's. These averaged values were used to determine an overall HSI.

Statistical Analysis:

In order to fulfill study objectives 1, 2, and 3, univariate correlation analyses were conducted on the data. Tests for correlations between evaluation species density and HSI Model values and between evaluation species density and habitat measurements were performed using the SAS, CORR procedure (SAS Institute Inc. 1985).

Three distinct multivariate procedures were employed in analyzing the data. Discriminant analysis was used to clarify a linear relationship observed in the univariate correlation analysis and the plots of evaluation species density versus habitat measurements. Principal Components Analysis (PCA) and Multiple Regression analysis for linear relationships were employed to explore for indirect relationships.

Discriminant Analysis, which is primarily exploratory, is a separatory procedure employed to discern differences between groups (Johnson and Wichern 1982). Discriminant Analysis attempts to describe the groups algebraically in a manner that maximizes the differences among the groups. The analysis was completed using the DISC computer function of SPSS. The Wilks lambda variable selection criteria option was chosen to complete the analysis.

Principal Components Analysis (PCA) is designed to reduce the dimensionality of a data set by exploring for relationships among the original data variables and, consequently, rewriting the data set in terms of a new data matrix of variables called Principal Components. Principal Components are uncorrelated linear combinations of the original variables. Each PC is the linear combination that accounts for the largest possible amount of unexplained variation in the data set. Ideally, PCA will identify underlying factors influencing the data set and simplify portrayal of the system being studied.

PCA's were completed using the SAS, PRIN COMP procedure (SAS Institute Inc. 1985) on the original habitat data. The analyses were completed using the correlations matrices.

Multiple regression tests for linear relationships among more than 2 variables (Steel and Torrie 1980). It is applicable to situations where more than 1 independent variable (habitat indices) may influence a dependent variable (evaluation species density). A multiple correlation coefficient indicates the extent of the relationship between the dependent variable and the independent variables' data set. The multiple regression results provide an equation of the relationship that may allow the identification of potentially significant variables in the relationship. The SAS, REG procedure (SAS Institute Inc. 1985) was employed to complete this analysis.

RESULTS AND DISCUSSION

Downy Woodpecker

Of the 4 models tested, the downy woodpecker model was considered most likely to predict successfully the evaluation species' density. The eurytopic life history of the downy woodpecker allowed construction of a simple model, which primarily focused on the species' lone stenotopic trait: snags for nesting. Lawrence (1973), Conner and Adkisson (1977) and Williams and Batzli (1979) documented the species' acceptance of a wide variety of habitat types. Best et al. (1982) considered the downy woodpecker, although tolerant to habitat alteration, highly dependent on snags (Best et al. 1982). Thus, the other variable, basal area (representing feeding cover), was utilized to portray remaining vital habitat characteristics.

Densities of downy woodpeckers on Harlan County Project woodlands ranged from 0.0 to 25.0 individuals/40 ha (Table 4). The overall average density was 11.9/40 ha. These densities were approximately comparable to other studies in eastern deciduous forests (Kendeigh 1944, Kendeigh 1946, Kendeigh and Fawver 1981, Tilghman and Rusch 1981). However, Willson (1974) observed significantly higher densities (24/40 ha [12 males/40ha]).

Downy woodpecker densities were significantly correlated with HSI, the SI for Variable Two (representing snag density), and snag density (Table 5). Examination of the data revealed a potential nonlinear relationship between basal area and species density (Figure 4).

Table 4. Downy woodpecker and black-capped chickadee densities observed on the Harlan County Project, Nebraska (1984).

Plot	Downy woodpecker	Black-capped chickadee
A	10.0	5.0
B	10.0	10.0
C	0.0	10.6
D	13.4	13.4
E	25.0	5.0
F	20.0	20.0
G	10.0	15.0
H	0.0	26.6
I	17.8	0.0
Overall density	11.9	11.9

Table 5. Correlations of downy woodpecker HSI Model scores, and woodland habitat measurements with estimates of downy woodpecker densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	P > |r|
HSI[1]	0.74	0.0231
SI One[2]	-0.47	0.2011
SI Two[3]	0.70	0.0362
Basal area	0.50	0.1691
Snag density	0.72	0.0293

[1] Habitat Suitability Index.

[2] Suitability Index One (basal area).

[3] Suitability Index Two (snag density).

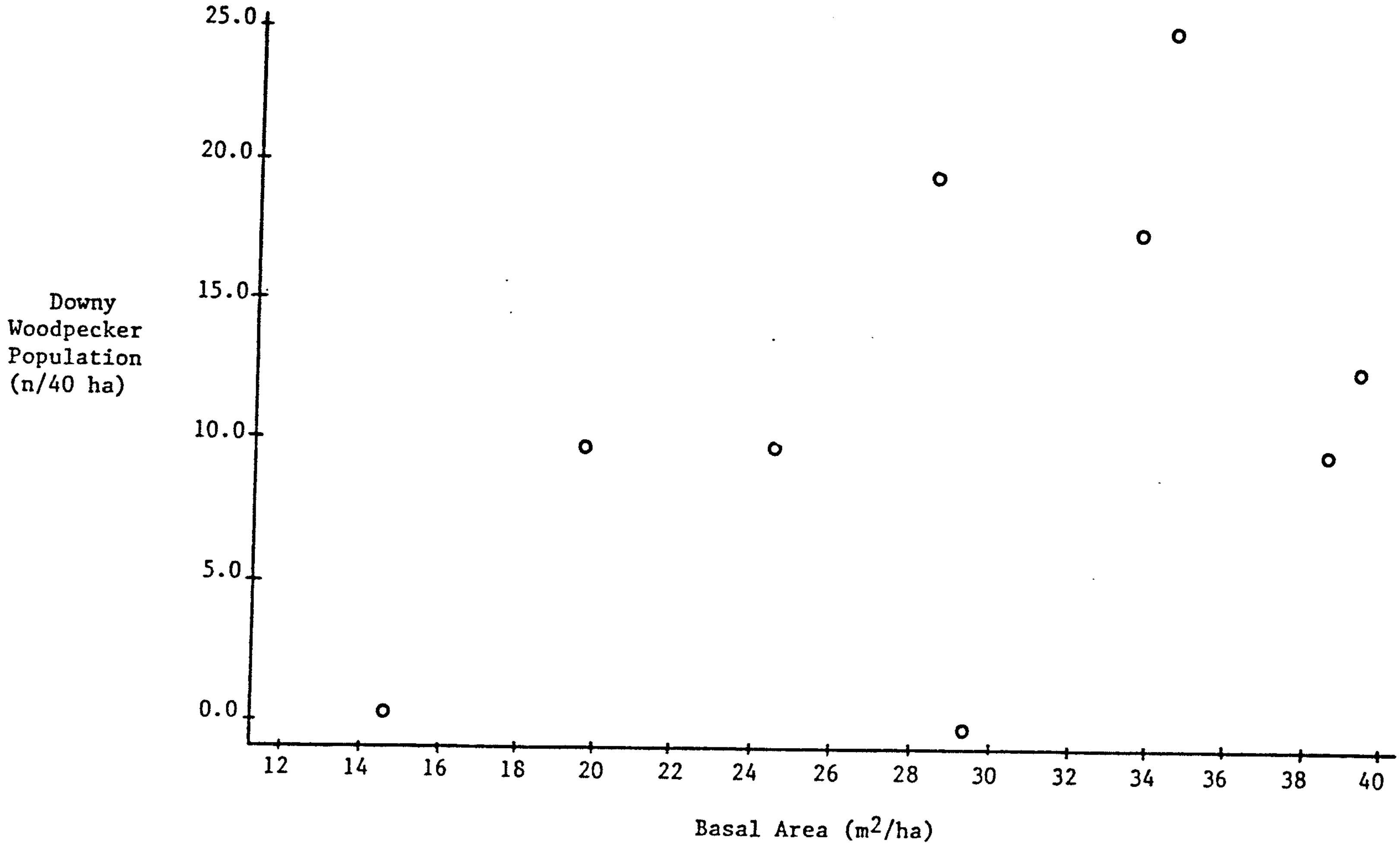
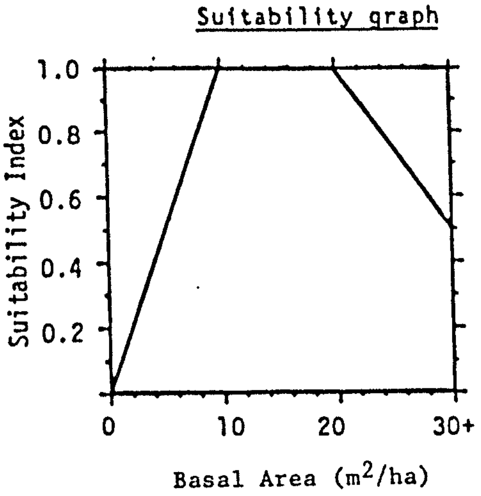


Figure 4. Downy woodpecker densities versus basal area from 9 woodland plots, Harlan County Reservoir, Nebraska (1984).

Based on the correlation analysis, the model appeared to successfully convert data to a quantitative value predicting habitat utilization. However, the correlation observed between HSI and population must be viewed as a marginal success. The slightly higher correlation between snag density (0.72) and population than between Variable Two SI (0.70) and population potentially revealed a potential model flaw. Data indicated that optimal snag densities were greater than the optimum predicted by the HSI Model (5+ snags/0.4 ha). However, combination of Variable One and Variable Two SI's provided an HSI with correlation values slightly superior to data relationships. Variable One, despite appearing unrelated statistically, did make a limited, valuable contribution to the analysis. Greater basal area, the result of maturing woodlands or dense woodland stands, were expected to generate a greater number of snags because of the predominance of shade intolerant species. However, basal area was uncorrelated with snag densities ($r = 0.17$, $PR > |R| = 0.2171$). Thus, shade tolerant species developing in the understory possibly contributed to basal area without an associated increase in snags.

The model was not entirely accurate in portraying the relationship between basal area and density (Figure 4). Sample population levels continued to increase to basal area values of 30-35 m^2/ha. Contrarily, the model assumed that suitability decreased after basal area exceeded 20 m^2 /ha. Consequently, the model was modified (Figure 5), so suitability was assumed to

A. Original model



B. Modified model

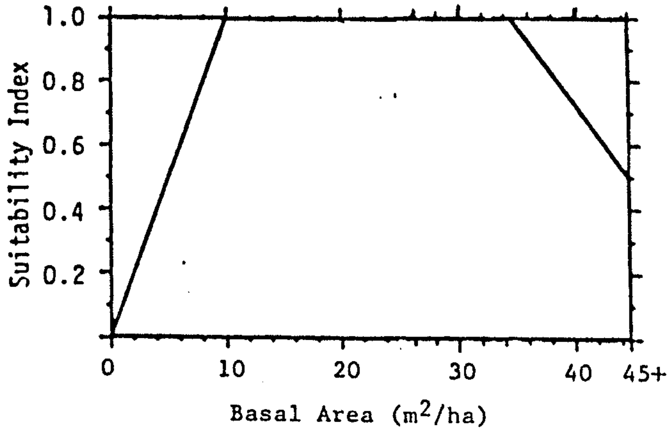


Figure 5. Original and modified versions of the SI Graphs for basal area from U.S. Fish and Wildlife Service downy woodpecker HSI Model, Harlan County Reservoir, Nebraska (1984).

decline after basal area exceeded 35 m^2 /ha. The negative relationship between Variable One SI values and population was dampened in the modified model. A somewhat greater correlation between the modified model's HSI's and population was observed (Table 6).

Evaluation of basal area in relation to downy woodpecker density revealed 2 potential relationships. An analysis of the data for a curvilinear relationships revealed a relatively strong correlation ($r = 0.83$, $PR > |F| = 0.0291$) when 2 outlier observations were (Figure 6) removed. Outlier 1 was dismissed because low snag density (0.0 snags/0.4 ha) probably limited woodpecker density. Outlier 2 was excluded because it was possible that mid season territory fluctuations may have caused an overestimate of density. The relationship portrayed by this test confirmed the model design. Figure 7 includes snag densities with the plot of basal area and woodpecker density. Group 1, which was dominated by low population estimates, featured the 4 lowest snag densities. Contrarily, Group 2, dominated by higher population estimates, featured extremely high snag densities. A correlation analysis of Group 2 between basal area and woodpecker density revealed a potential negative correlation ($r = -0.66$, $PR > |R| = 0.2297$). Snag densities for Group 2 were probably far in excess of minimal densities for optimum. Thus the relationship detected also supported the relationship predicted by the HSI Model (habitat suitability decline as basal area increases beyond a critical maximum).

Table 6. Correlations of adjusted downy woodpecker HSI Model scores with estimates of downy woodpecker densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	$P > \lvert r \rvert$
HSI[1]	0.79	0.0113
SI One[2]	-0.11	0.7861
SI Two[3]	0.70	0.0362

[1] Habitat Suitability Index.

[2] Suitability Index One (basal area).

[3] Suitability Index Two (snag density).

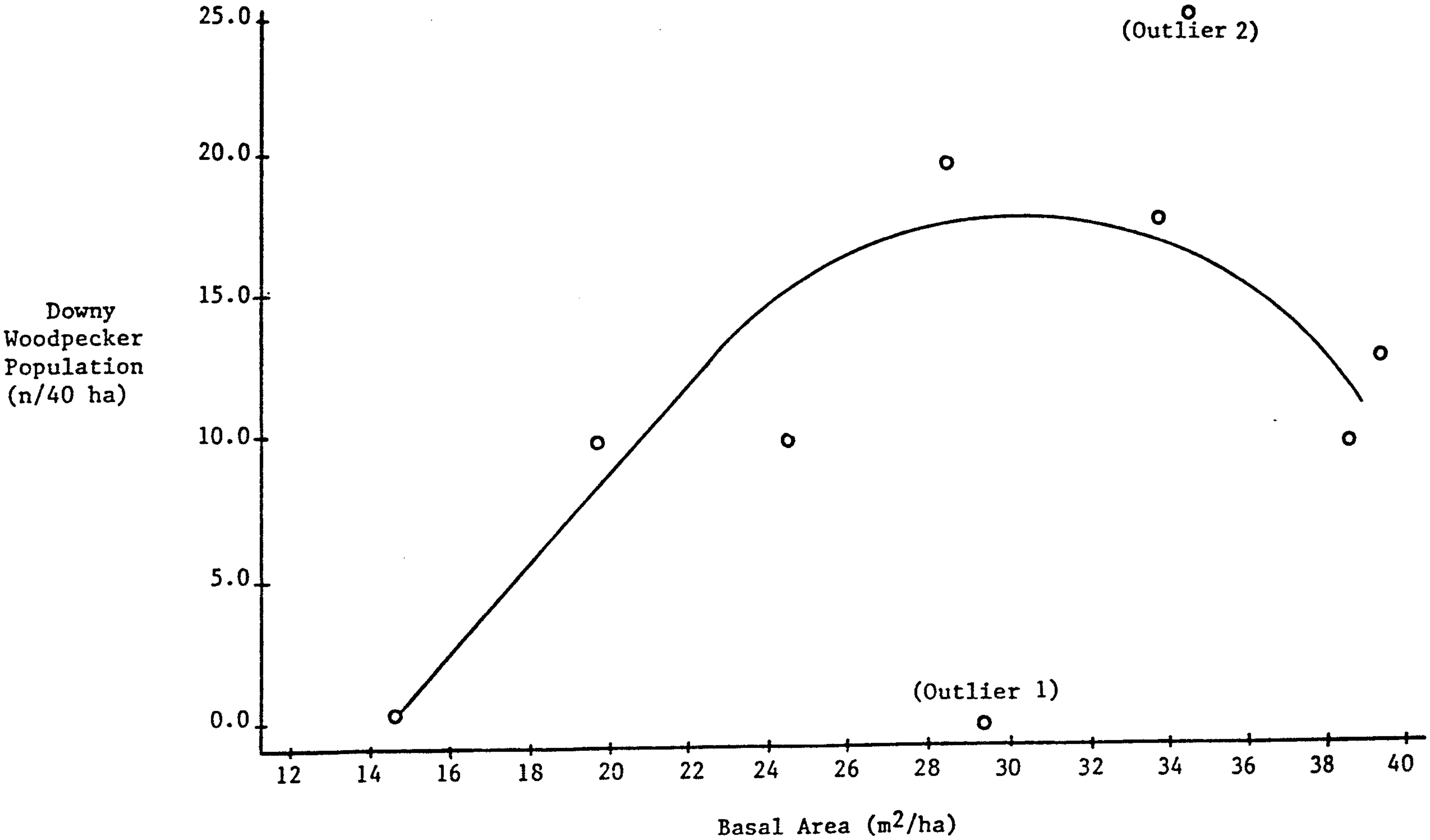


Figure 6. Downy woodpecker densities versus basal area from 9 woodland plots indicates a potential curvilinear relationships (excluding outliers), Harlan County Reservoir, Nebraska (1984).

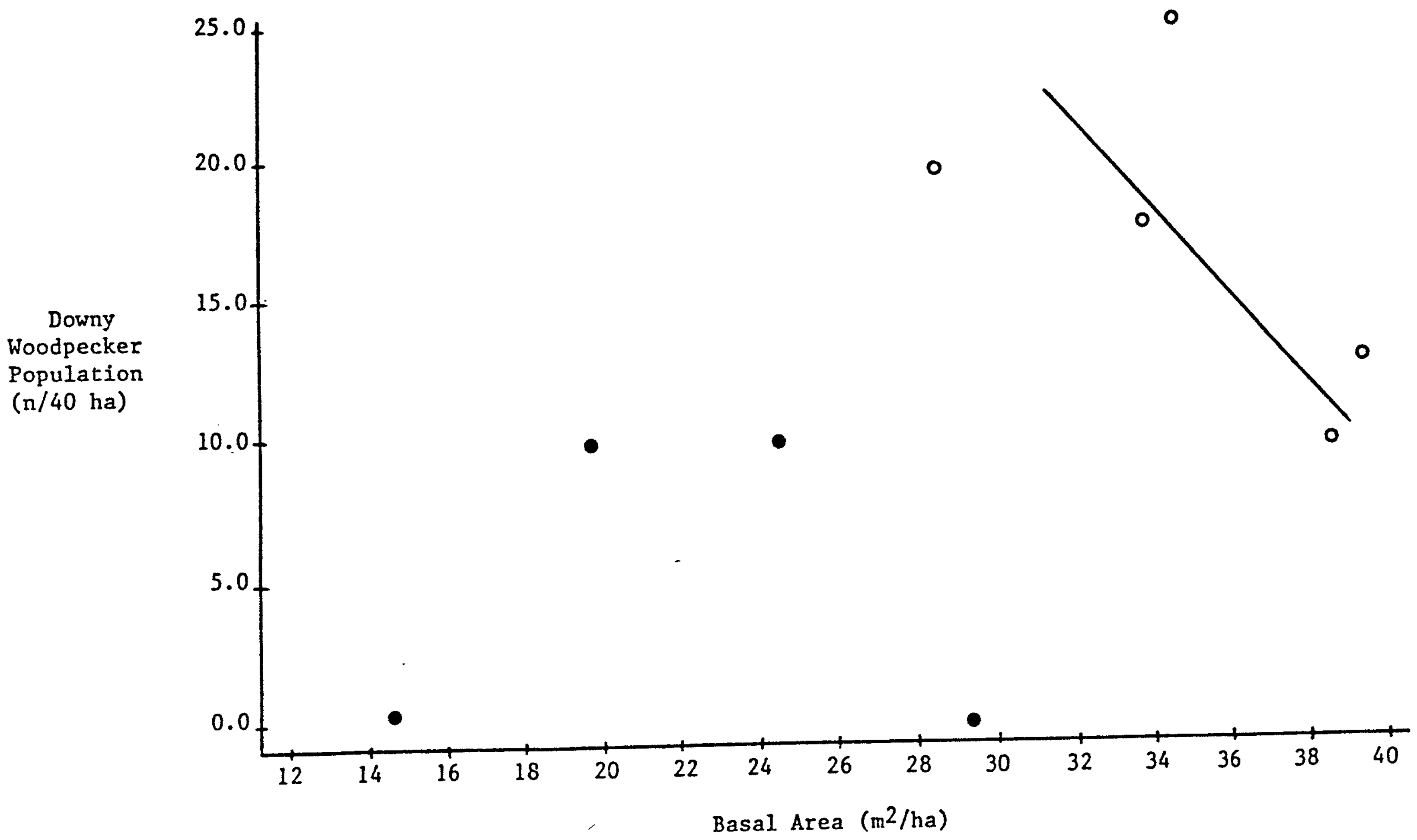


Figure 7. Downy woodpecker densities versus basal area from 9 woodland plots, Harlan County Reservoir, Nebraska (1984). Woodland study plots were separated into groups based on snag densities (closed circles represent low snag densities, open circles represent high snag densities).

Although univariate analyses demonstrated that the model was successful in predicting downy woodpecker densities, a multiple regression test was conducted using the 2 habitat variables employed by the model to determine whether a stronger relationship could be detected. The analysis failed to generate evidence of a significant relationship (PR > F = 0.1041, Multiple Correlation Coefficient = 0.53).

Field testing of the USFWS downy woodpecker HSI Model demonstrated that the calculated HSI correlated with population density. Modification of a SI Graph for basal area caused only a slight increase of the success of this test. The downy woodpecker is a highly adaptable species with 1 primary limiting habitat requirement, snag density, which simplifies interpretation of habitat needs and development of a valid evaluation model.

Black-capped Chickadee

The black-capped chickadee HSI Model, which identified 3 habitat variables, was somewhat more complex than the downy woodpecker HSI Model. Overstory canopy cover and overstory height were utilized to describe feeding cover; snag density was employed to portray nesting cover. However, the variables describing feeding cover were not factually linked to the species by any study. Rather, they were alternative measurements for a more difficultly measured variable, canopy volume, which was linked directly to the black-capped chickadee..

The overall black-capped chickadee density (all woodland plots combined) on the Harlan County Project was comparable (11.9/40 ha) to other reported densities in eastern deciduous forests (Kendeigh 1944 [12.6/40 ha], Kendeigh 1946 [18/40 ha], Stewart and Aldrich 1949 [4-14/40 ha], and Tilghman and Rusch 1981 [7.12/40 ha]). Chickadee densities observed by Willson (1974) and Kendeigh and Fawver (1981) (20.0/40 ha in both studies) were higher than densities observed on the Harlan County Project. Densities on woodland plots at Harlan County ranged from 0.0-26.6/40 ha (Table 4).

No significant positive correlations were detected between black-capped chickadee densities and HSI Model values or habitat variables (Table 7). Significant negative correlations were observed between population and the Food LRV, Variable Two SI's, and tree canopy height. Thus, the model was not successful in predicting habitat usage.

Habitat measurements for the Food LRV were not diverse and tended to concentrate values near 1 segment of SI Graphs. All but 1 sample plot provided average height measurements exceeding the maximum value on the SI Graph and were accordingly attributed a SI value of 1.00. However, the correlation analysis revealed a negative relationship between canopy height and chickadee densities. No correlation was detected between canopy closure and height ($r = 0.11$, $P > |R| = 0.4334$). Comparison of the proportion of visual (influenced by overstory canopy height) and aural (less likely to be influenced by overstory canopy height) to canopy height revealed no correlation ($r = 0.22$, $P > |R| = 0.4268$).

Table 7. Correlations of black-capped chickadee HSI Model scores, and woodland habitat measurements with estimates of black-capped chickadee densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	P > |r|
HSI[1]	-0.37	0.3272
Food LRV[2]	-0.76	0.0179
SI One[3]	-0.34	0.3713
SI Two[4]	-0.88	0.0018
SI Four[5]	-0.35	0.3565
Canopy cover	-0.66	0.0550
Canopy height	-0.83	0.0061
Snag density	-0.36	0.3456

[1] Habitat Suitability Index.
[2] Food Life Requisite Value.
[3] Suitability Index One (Canopy cover).
[4] Suitability Index Two (Canopy height).
[5] Suitability index Four (Snag density).

Thus, it was doubtful that canopy height influenced detectability of individuals.

Evaluation of plots (Figures 8 and 9) for population and tree height, and population and canopy cover suggested that SI Graph modifications may help improve the predictive capabilities of the model. Unfortunately, the habitat contrasts provided by the sample plots were inadequate to allow conclusive interpretations regarding the habitat preferences of the species. These trends might have indicated an aversion to overmature forest conditions that stunt understory growth.

Therefore, the SI Graphs for canopy cover and tree height were modified to represent negative trends observed at the greater end of the habitat measurements (Figures 10 and 11). Subsequent correlation analyses (between HSI's and population) still failed to identify positive relationships despite these model modifications (Table 8).

A multiple regression analysis utilized to evaluate relationships of densities with habitat data detected a significant relationship (PR > F = 0.0272). A Multiple Correlation Coefficient of 0.82 was obtained for the raw data. Thus, chickadee abundance appeared to be related to the habitat variables in some manner.

The implication of these results is that the HSI model for the chickadee did not correctly describe habitat conditions. In fact, the HSI's, LRV's, and SI's are misleading (negatively

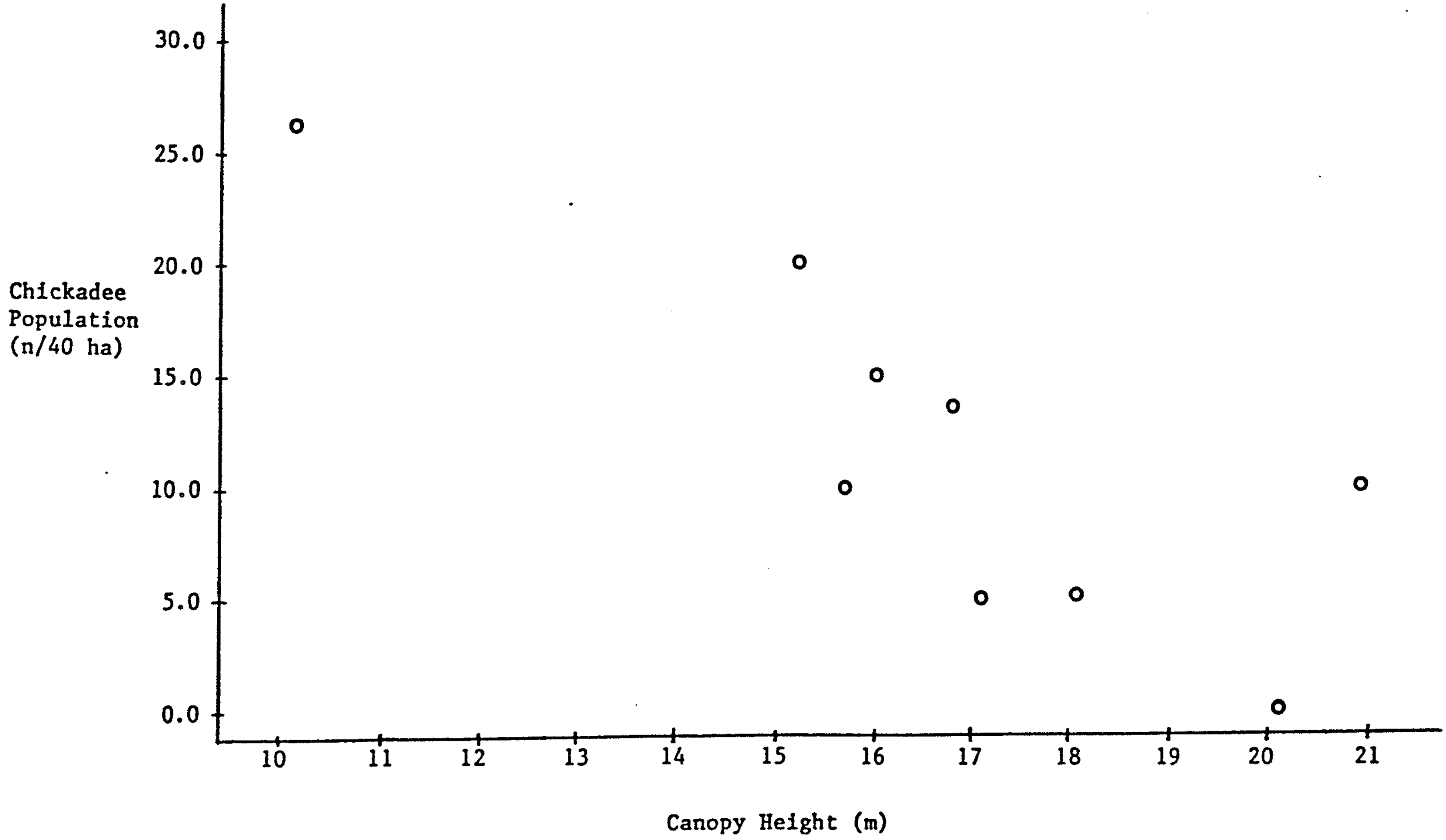


Figure 8. Black-capped chickadee densities versus canopy height from 9 woodland plots, Harlan County Reservoir, Nebraska (1984).

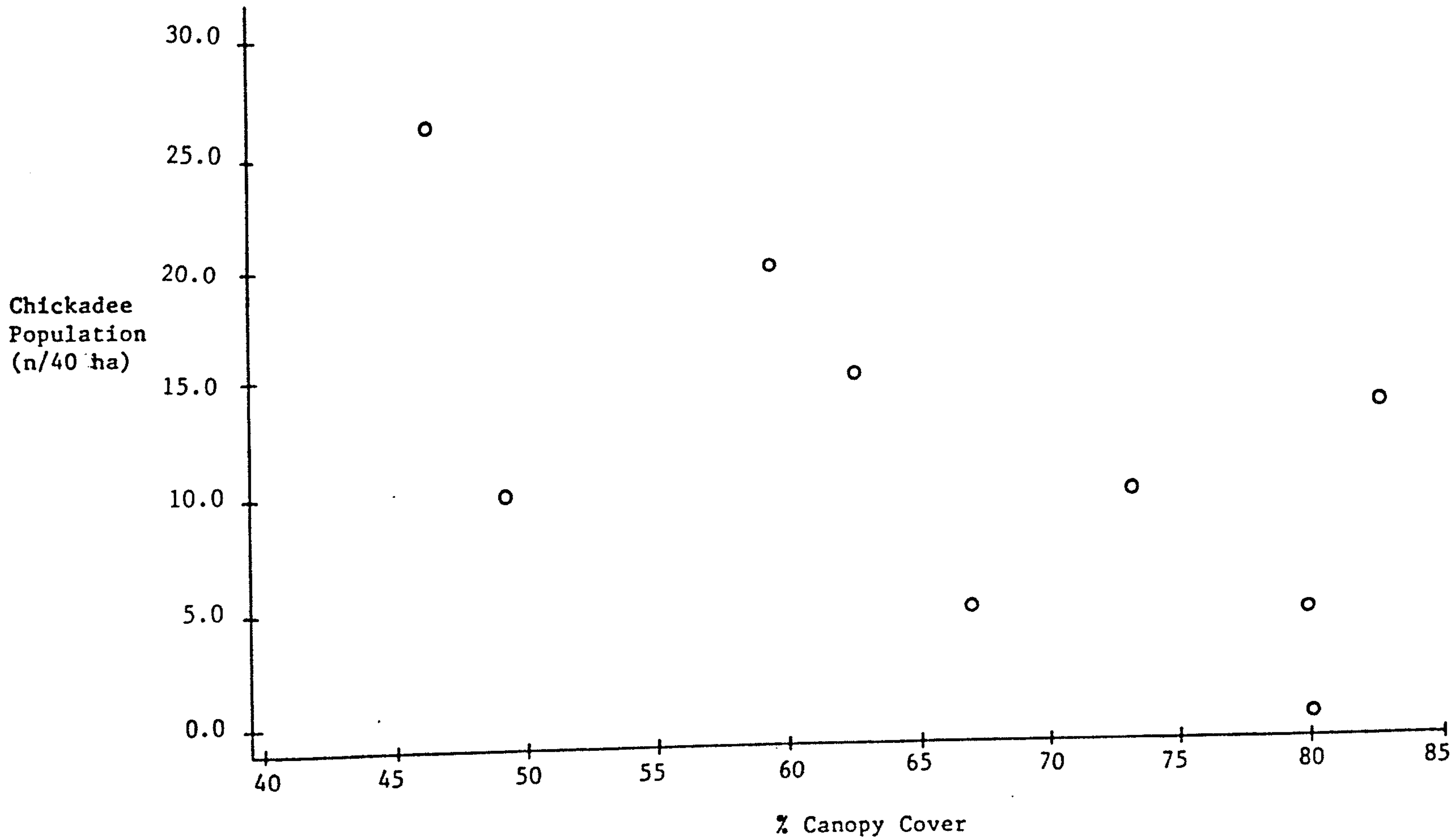
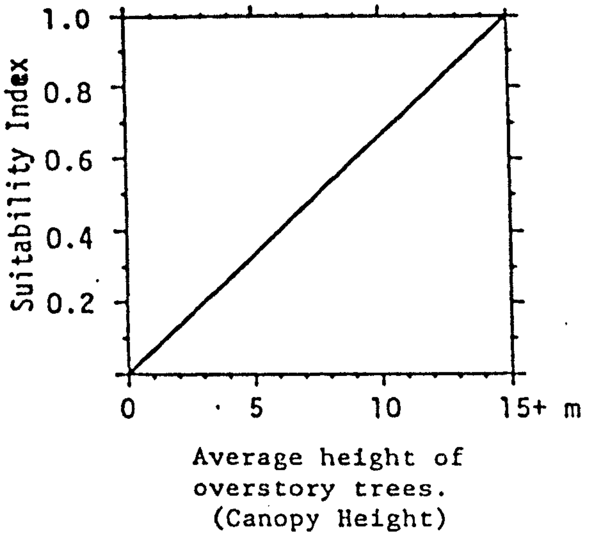


Figure 9. Black-capped chickadee densities versus canopy cover from 9 woodland plots, Harlan County Reservoir, Nebraska (1984).

A. Original model.



B. Modified model.

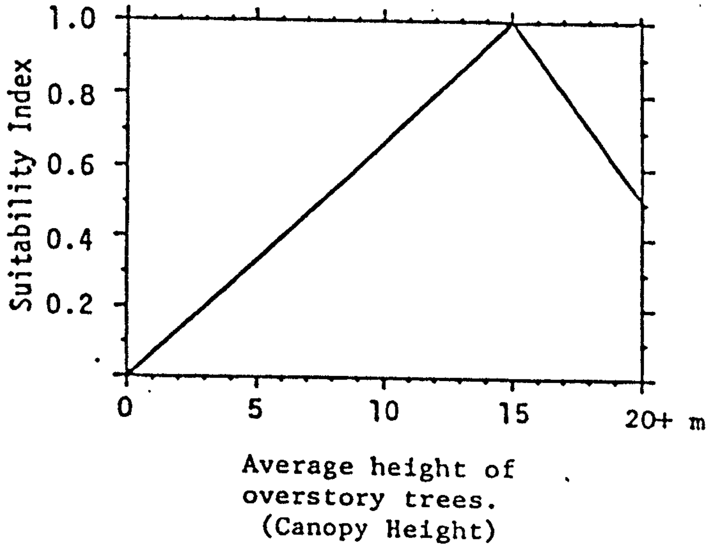
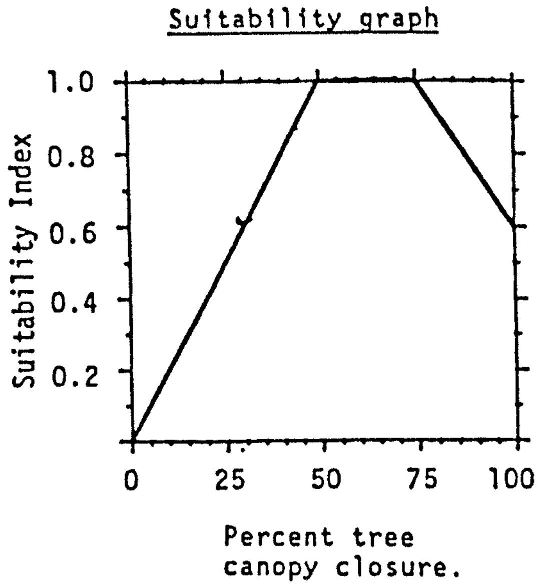
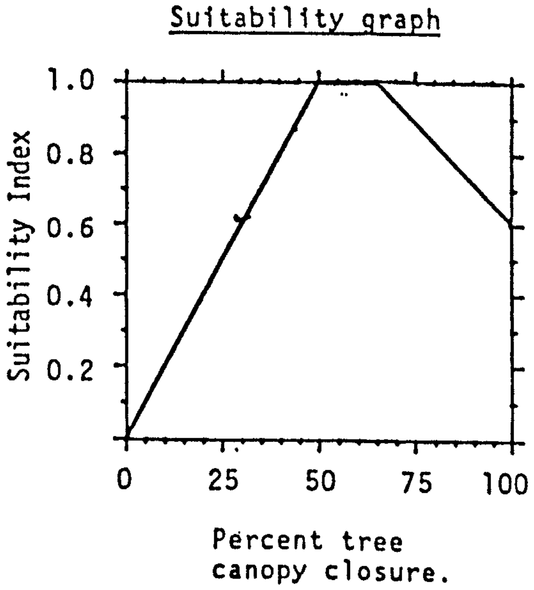


Figure 10. Original and modified versions of the SI Graphs for average height of overstory trees from U.S. Fish and Wildlife Service black-capped chickadee HSI Model, Harlan County Reservoir, Nebraska (1984).

A. Original model.



B. Modified model



(Canopy Cover)

Figure 11. Original and modified versions of the SI Graphs for percent tree canopy closure from U.S. Fish and Wildlife Service black-capped chickadee HSI Model, Harlan County Reservoir, Nebraska (1984).

Table 8. Correlations of adjusted black-capped chickadee HSI Model scores with estimates of black-capped chickadee densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	$P > \lvert r \rvert$
HSI[1]	-0.42	0.2655
Food LRV[2]	0.02	0.9493
SI One[3]	0.03	0.9353
SI Two[4]	0.04	0.9164
SI Four[5]	-0.35	0.3565

[1] Habitat Suitability Index.
[2] Food Life Requisite Value.
[3] Suitability Index One (Canopy cover).
[4] Suitability Index Two (Canopy height).
[5] Suitability index Four (Snag density).

correlated with density). Thus, the model appears to be designed incorrectly based on these data. However, application of the model on sample plots providing limited habitat contrasts forced potentially inappropriate interpretation of subtle habitat differences.

Multivariate analysis indicated that the habitat measurements identified in the model were related to population levels. Thus, the model identified important habitat parameters for qualitatively assessing black-capped chickadee habitat. The relationship between chickadee density and the habitat parameters remained unclear.

The failure to detect a positive relationship between chickadee densities and snag densities was a result of the extremely high snag densities throughout the study area. Since snags were in abundance, other habitat factors probably determined chickadee densities. Previous research provided adequate evidence documenting the chickadees' tendency to occupy a wide variety of forest habitats and justifying the expectation of a positive relationship between population levels and snag densities (Brewer 1963, Tyler 1964, Evans and Conner 1979, Thomas 1979)

In summary, the black-capped chickadee HSI Model failed to predict chickadee densities because of inappropriate structure of SI Graphs. However, the model successfully identified habitat measurements that were related to evaluation species' densities. It did not appear that the chickadee evaluation model failed because the species' habitat requirements were too complex to interpret. In fact, relationships between the habitat and chickadee densities were observed (Table 7). Thus, to construct an accurate model, additional information defining these relationships is necessary.

Meadowlark

Grassland habitat was evaluated using the USFWS HSI Model for the eastern meadowlark. Although western meadowlarks were more common on the study area than eastern meadowlarks, the habitat requirements were considered sufficiently similar to justify usage of the model.

The TRANSECT program was used by combining all the meadowlark observations from the 21 transects, to allow generation of an overall density estimate for the Harlan County Project. A moderate density of meadowlarks was observed on the Harlan County Project (9.1/40 ha for all transects combined) (Table 9). Higgins et al. (1984) reported a density of 5.8/40 ha (North Dakota). Willson (1974) reported a density of 26/40 ha (Illinois).

No strong correlations were detected between population levels and HSI Model values (HSI's, LRV's, or SI's) or habitat measurements (Tables 10 and 11). Review of plots of meadowlark density versus habitat variables did not reveal evidence of nonlinear relationships. However, the plot for average height of herbaceous canopy versus meadowlark densities was considered to potentially reflect a trend predicted by the model's SI (Figure 12).

Table 9. Meadowlark and grasshopper sparrow densities observed on the Harlan County Project, Nebraska (1984)

Transect	Meadowlark*	Grasshopper sparrow*
1	3	3
2	2	2
3	6	6
4	9	9
5	5	5
6	2	2
7	11	11
8	6	6
9	0	0
10	4	4
11	3	3
12	0	0
13	7	7
15	2	2
16	3	3
17	5	5
18	7	7
19	4	4
20	1	1
21	5	5
Overall density (n/40 ha)	9.1	35.3

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* Number of individuals observed in a 1000 m transect, 100 m wide (10 ha).

Table 10. Correlations of Meadowlark HSI Model scores with estimates of meadowlark densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	$P > \lvert r \rvert$
HSI[1]	0.22	0.3453
SI One[2]	0.12	0.6254
SI Two[3]	-0.18	0.4351
SI Three[4]	0.45	0.0441
SI Four[5]	-0.01	0.9584
SI Five[6]	-0.19	0.4111

[1] Habitat Suitability Index.

[2] Suitability Index One (Herbaceous cover).

[3] Suitability Index Two (Proportion of herbaceous cover occurring as grass).

[4] Suitability Index Three (Average herbaceous vegetation height).

[5] Suitability Index Four (Distance to perch).

[6] Suitability Index Five (Shrub cover).

Table 11. Correlations of habitat measurements with estimates of meadowlark densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	P > |r|
Herbaceous cover	0.16	0.5125
Proportion grass	-0.13	0.5721
Average height	-0.47	0.0380
Distance to perch	-0.31	0.1910
Shrub cover	0.04	0.8795

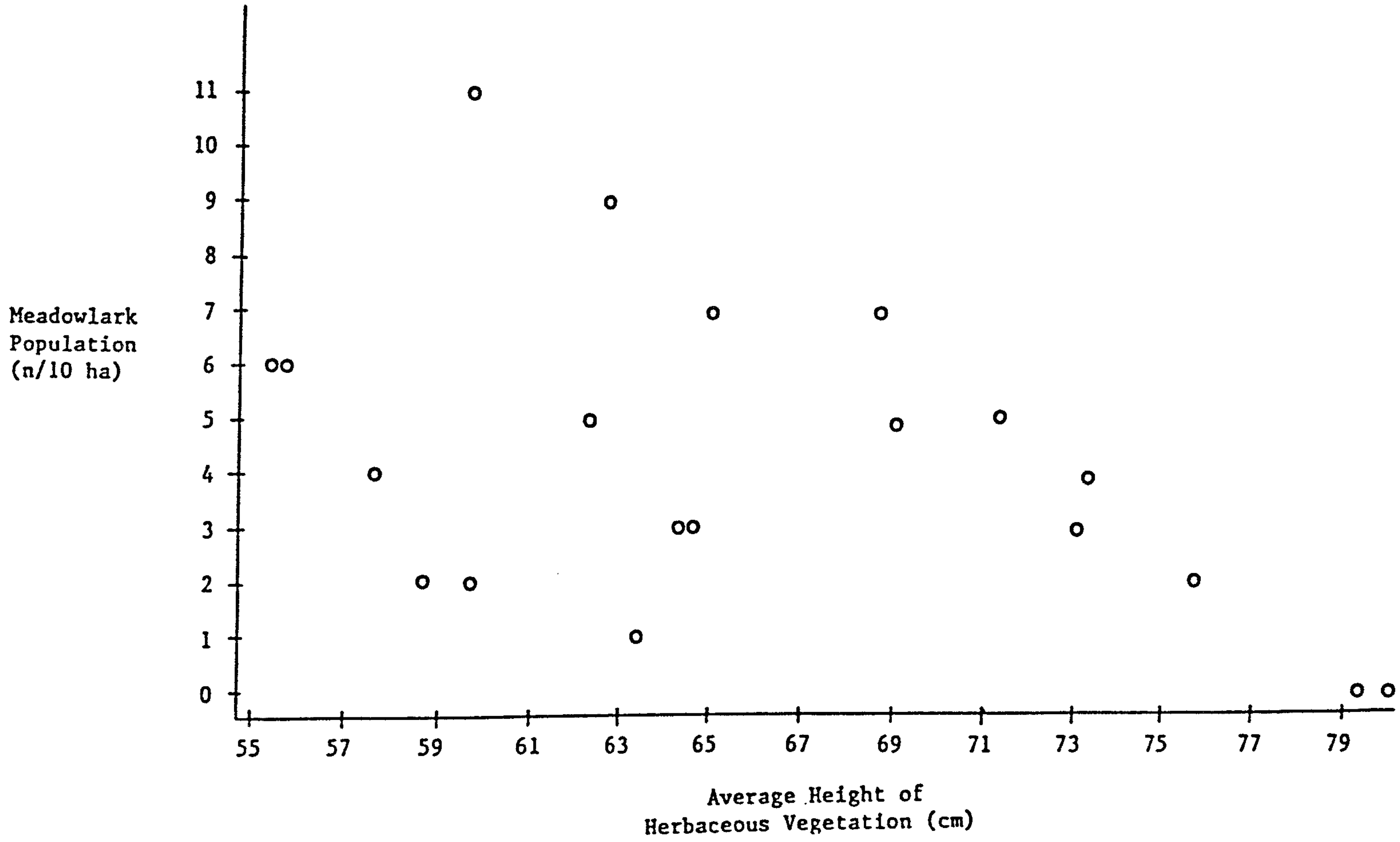

Figure. 12. Meadowlark densities versus average height of herbaceous canopy from 20 grassland transects, Harlan County Reservoir, Nebraska (1984).

The evaluation model predicted a negative relationship between habitat quality and average heights of herbaceous canopy exceeding 40 cm. Herbaceous vegetation heights varied considerably among sample sites and dates of data collection. The height data were separated into 3 groups (Figure 13) because the timing of sampling was spread over a 1 month period, resulting in wide diversity of habitat conditions. A discriminant analysis was carried out to determine if the differences were statistically significant. Sufficient levels of significance were observed (Table 12) to justify a correlation analysis of each group separately.

High negative correlations ($r > -0.9$) (Table 13) were observed between meadowlark densities and herbaceous canopy height for all 3 groups. However, this analysis demonstrates that the relationship of height and evaluation species density may fluctuate with external factors (e.g. time, grassland productivity). Thus, height may not be the cause of meadowlark density declines so much as an indirect measure of the true factor. The discriminant analysis utilized the habitat variables for herbaceous vegetation height, and proportion of herbaceous canopy of forbs to distinguish the groups. Height was interpreted to reflect vegetative production in grassland. Forb proportion probably represented topographical location in grassland (upland vs lowland grassland retrogression and date of data collection. Forb cover was very weakly correlated to sample date ($r = 0.35$, $P > |R| = 0.0229$). Retrogression was typified by excessive litter

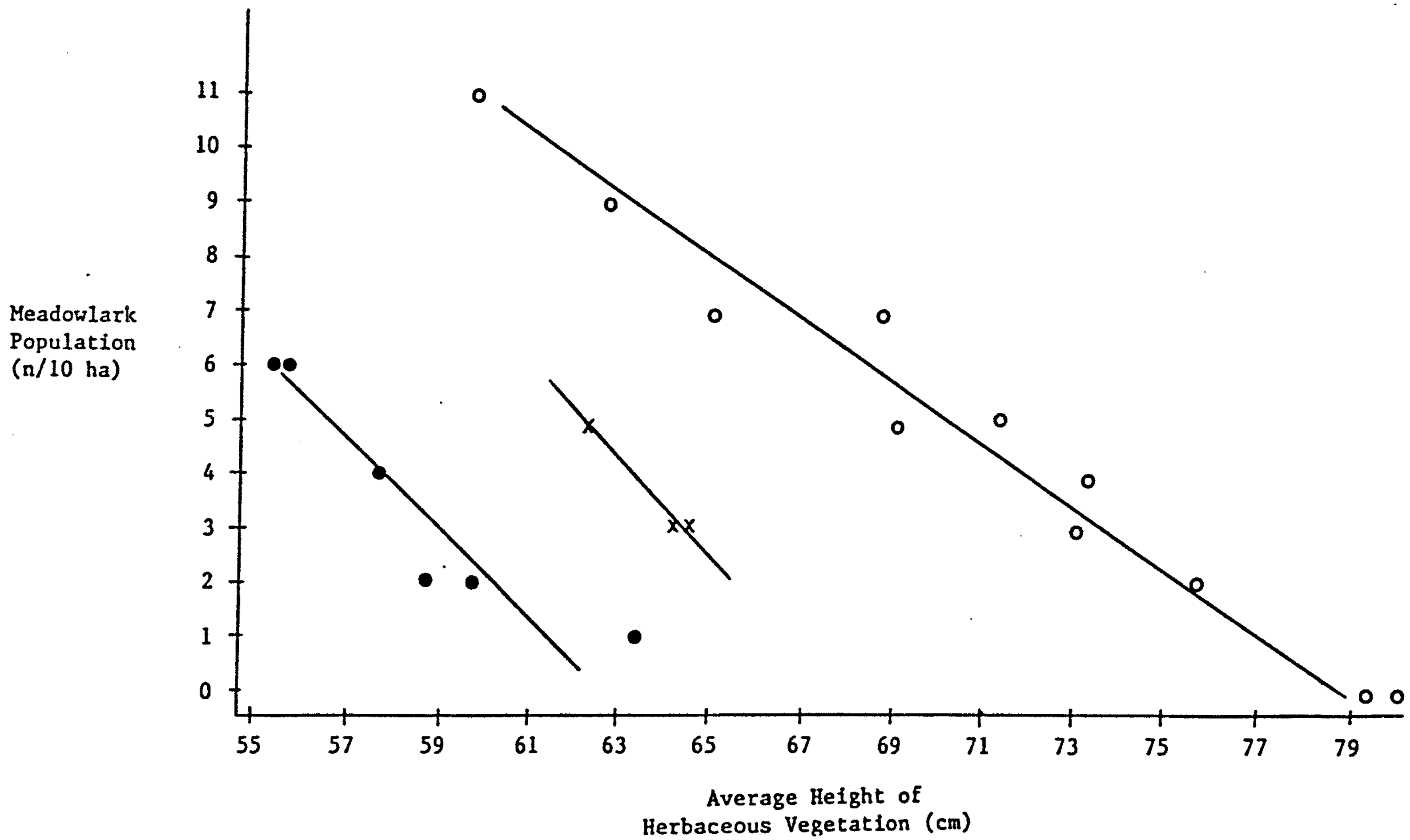

Figure 13. Meadowlark densities versus average height of herbaceous canopy from 20 grassland transects, Harlan County Reservoir, Nebraska (1984). Transects, separated into 3 groups based on Discriminant Analysis, indicate an inverse relationship between meadowlark densities and average height of herbaceous vegetation. Discriminant analysis separated Groups 1 (O), 2 (●), and 3 (X) based on habitat measures reflective of date of data collection and site productivity.

Table 12. Results of discriminant analysis F-test describing differences between groups identified in meadowlark habitat evaluation, Harlan County Reservoir, Nebraska (1984).

	Group 1	Group 2	
Group 2	13.41 0.0004	--	F-statistic PR > F
Group 3	1.85 0.1893	3.00 0.0783	F-statistic PR > F

Table 13. Correlations between meadowlark density estimates and average herbaceous canopy height by groups of data separated in Discriminant Analysis, Harlan County Reservoir, Nebraska (1984).

	Group 1	Group 2	Group 3
Correlation Population x Height	-0.99	-0.92	-0.98
PR > |R|	0.0001	0.0083	0.1160

accumulation, reduced herbaceous production, and higher proportions of forb cover.

Multivariate analyses also failed to detect any significant relationships. Multiple regression analysis for habitat measurements and for Principal Component Scores failed to identify significant relationships. Principal Components Analysis did not reduce the dimensionality of the data set.

Failure to detect relationships between habitat parameters and species' densities is not necessarily indicative of inherent model faults. Failure to detect relationships may be attributed to the sample pool and timing of data collection.

The range of conditions available for sampling was limited. Consequently, little contrast was present for sample comparisons (e.g. Herbaceous Canopy Cover values ranged from 46% to 71%, Average Herbaceous Canopy Height ranged from 55 cm to 76 cm, and Shrub Canopy Cover ranged from 0% to 13%). A user of the model may not be capable of detecting habitat quality differences when values are clustered on the SI Graphs because of inadequate habitat contrasts.

Additionally, sampling of grasslands extended through the spring (May and June). During this period vegetative conditions changed dramatically. The interaction between sample date and vegetation development likely confounded the data sufficiently to prevent detection of relationships. Correlations were detected between the date of data collection and 2 habitat measurements of the meadowlark. The proportion of the herbaceous canopy cover composed of grass was weakly, negatively correlated with date of data collection (r = -0.41, PR > |R| = 0.0074). A weak negative correlation between distance to a potential perch site and date was detected (r = -0.65, PR > |R| = 0.0001). This occurred because erect forbs such as mullein and yucca had additional time to develop. Percent forb canopy was very weakly, significantly correlated to data collection date (r = 0.35, PR > |R| = 0.0229).

Measurements suggested by the models were unusual range measurements, although common in forest sampling (e.g. herbaceous canopy cover using the line intercept method, average height of herbaceous canopy using a graduated rod with the line intercept method). According to the model, feeding and reproductive habitat suitability are related to the height and density of herbaceous vegetation. The HSI Model specifically indicates that herbaceous vegetation height and density are used as structural measures of the habitat ("feeding and reproductive habitat suitability for the eastern meadowlark is related to the height and density of herbaceous vegetation"). The visual obstruction measurement technique tested by Robel et al. (1970), which evaluates vegetation height and density in tandem, is widely accepted and utilized. Contrarily, application of line intercept sampling for herbaceous vegetation foliar cover is unrealistic. Line intercept sampling measures vertical projection of vegetation over a sample transect. Measurement of grass blade and culm widths over a sample line, obviously, is inefficient and inappropriate given the availability of other methods. Finally, no definition of what constitutes a canopy layer in grassland is presented. Thus, the model, while accurately identifying conditions that influence habitat suitability (height and density), may call for inappropriate methods of portraying habitat conditions.

Finally, the model may have failed to detect relationships between model values and meadowlark densities because the relationships are not adequately defined or understood. The complete failure to detect predictable interactions between populations and habitat data collected for the evaluation model could be evidence that no relationships exist, or that these habitat measurements, which may be related to true, critical habitat factors for the meadowlark (thus explaining previous results and model construction), are not directly related to the species' habitat selection process.

The meadowlark model, as applied, did not successfully predict evaluation species' densities. Construction of a valid evaluation model for the meadowlark was considered unlikely because of the complex relationship between the species and its habitat, and the paucity of quantitative studies linking the meadowlark to habitat conditions. No vitally important unidimensional habitat characteristic, such as snags, occurs as a habitat requirement. Failure of this validation effort may be attributed to several sources. Limited habitat contrasts were provided by the sample pool. Timing of data collection (sample date) may have compromised the value of the vegetative data. It is possible that inappropriate data were collected for habitat portrayal, and/or there is an inadequate definition or understanding of the biological relationships. Finally, data may be the result of an abnormal case.

Grasshopper Sparrow

The grasshopper sparrow habitat evaluation model was adapted from 2 models developed for Missouri (Baskett et al. 1980, Urich et al. 1983). The model utilized the most habitat measurements (7) of the 4 models subjected to validation testing. Validation of the model was considered unlikely because of the large number of variables. Inclusion of 7 habitat measurements in the model was considered a reflection of limited understanding of species/habitat interactions, or a relatively complex relationship between habitat conditions and species utilization. Although 7 measurements are not necessarily too many variables for an accurate model, greater numbers of variables increase the opportunity for errors.

The overall grasshopper sparrow densities (using the TRANSECT program with data from all transects combined) on the Harlan County Project was 35.3/40 ha (Table 9). This density was comparable with the density reported by Willson (1974) (30/40 ha) and greater than densities observed by Higgins et al. (1984) (17.3/40 ha). However, these densities were far below the maximum density predicted by Urich et al. (1983) (247/40 ha).

Only 1 significant relationship was detected between population levels and model values or habitat data (Table 14 and 15). Review of plots for nonlinear relationships did not reveal trends (Figure 14). Multiple regression analysis of habitat data failed to identify a relationship.

Principal Components Analysis of the 7 habitat variables, conducted to determine if the data could be concentrated in a few underlying components, failed to reduce dimensionality (Table 16). Multiple regression analysis of PC scores for the analyses failed to provide conclusive results. A potential trend was detected (PR > F = 0.0568) relating grasshopper sparrow densities with the PC scores for the analysis. A multiple correlation coefficient of 0.6197 was generated; stepwise multiple regression loadings concentrated heavily on Principal Component 4, and moderately on Principal Components 3 (positively) and 5 (negatively) (Table 17). Principal Component 4 featured a heavy positive loading (eigenvectors) on average herbaceous vegetation canopy height and a moderate, negative loading on litter depth (Table 18). Thus, PC 4 might be interpreted as representing the quality of the grassland and resistance to retrogression i.e. stunting of herbaceous growth by excessive litter accumulation. Principal Component 3, which featured moderate loadings on litter depth (negative) and woody invasion (positive), was considered an artifact of the data or analysis because no apparent biological explanation was evident. Principal Component 5, which loaded positively on forb cover, litter depth, and woody invasion, was

Table 14. Correlations of Grasshopper sparrow HSI Model scores with estimates of grasshopper sparrow densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	P > |r|
HSI[1]	-0.03	0.9107
SI One[2]	-0.34	0.1490
SI Two[3]	0.12	0.6212
SI Three[4]	0.57	0.0087
SI Four[5]	-0.31	0.1892
SI Five[6]	0.10	0.6780
SI Six[7]	-0.34	0.1380
SI Seven[8]	0.30	0.2011

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[1] Habitat Suitability Index.
[2] Suitability Index One (Average herbaceous vegetation height).
[3] Suitability Index Two (Height diversity).
[4] Suitability Index Three (Woody cover).
[5] Suitability Index Four (Litter depth).
[6] Suitability Index Five (Forb cover).
[7] Suitability Index Six (Herbaceous cover).
[8] Suitability Index Seven (Distance to water).

Table 15. Correlations of habitat measurements with estimates of grasshopper sparrow densities, Harlan County Reservoir, Nebraska (1984).

Variable	Correlation with Population	P > |r|
Average height	0.50	0.0249
Height diversity	0.09	0.6943
Woody cover	0.01	0.9514
Litter depth	-0.31	0.1772
Forb cover	-0.14	0.5503
Herbaceous cover	-0.33	0.1516
Distance to water	-0.32	0.1653

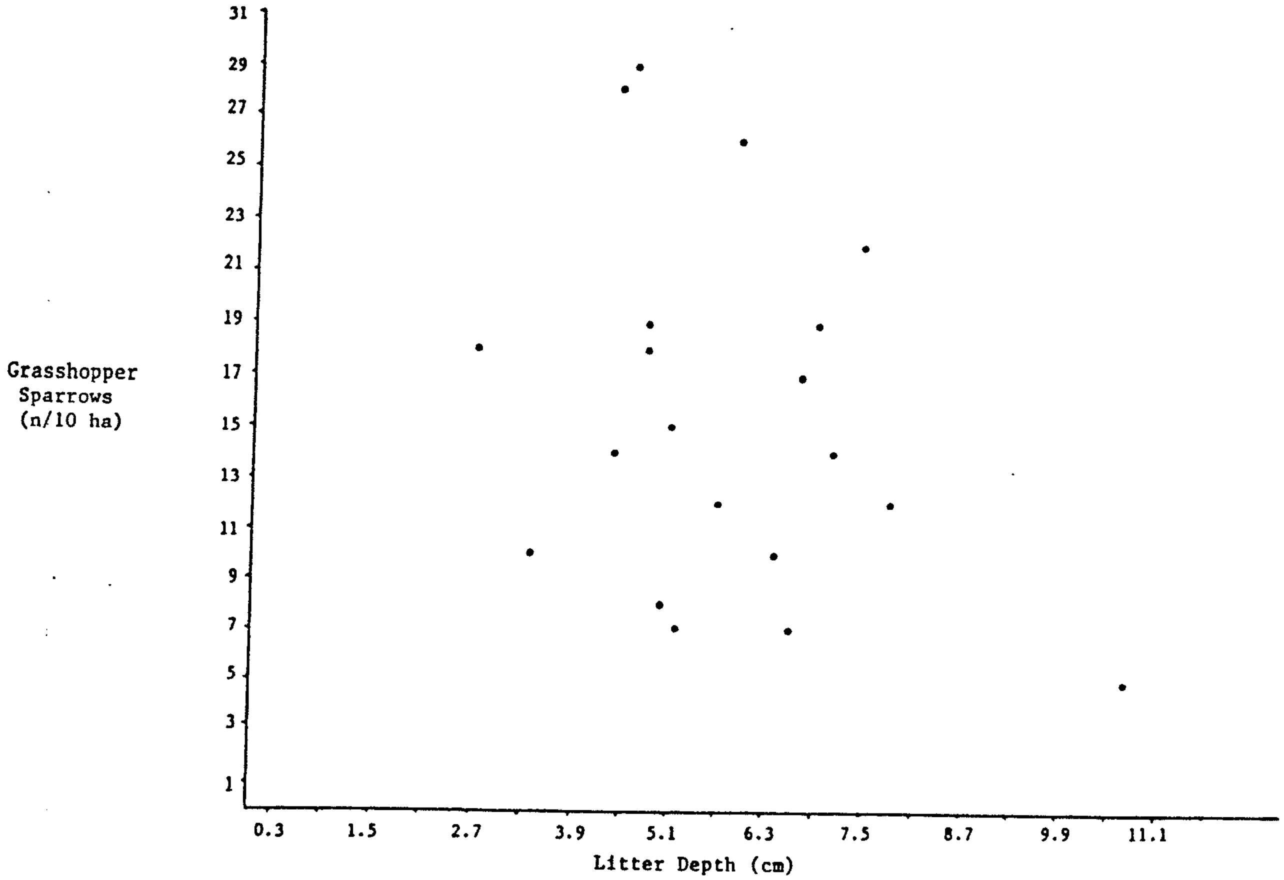

Figure 14. Grasshopper sparrow densities versus litter depth from 20 grassland transects, Harlan County Reservoir, Nebraska (1984). A portrayal of a typical relationship between habitat measurements and grasshopper sparrow densities.

Table 16. Principal Components Analysis results on 7 habitat measurements collected for grasshopper sparrow habitat evaluation, Harlan County Reservoir, Nebraska (1984).

Principal Component	Eigenvalue	Proportion	Cumulative
1	1.72	0.25	0.25
2	1.44	0.21	0.46
3	1.09	0.15	0.61
4	0.94	0.13	0.74
5	0.86	0.12	0.86
6	0.69	0.10	0.96
7	0.26	0.04	1.00

Table 17. Multiple regression results for grasshopper sparrow Principal Components and populations, Harlan County Reservoir, Nebraska(1984).

Variable	Parameter Estimate	T for H_0: Parameter = 0	Prob > |T|
Intercept	24.44	1.26	0.23
PC 1	-0.18	-0.74	0.47
PC 2	-0.07	-0.31	0.76
PC 3	0.84	1.68	0.12
PC 4	1.18	3.13	0.01
PC 5	-0.81	-1.97	0.07
PC 6	0.23	0.71	0.49
PC 7	-0.37	-1.24	0.24

Table 18. Eigenvectors generated by Principal Components Analysis conducted on habitat measurements collected for grasshopper sparrow habitat evaluation, Harlan County Reservoir, Nebraska (1984).

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Distance to water	0.56	-0.38	0.17	-0.01	-0.28	-0.33	0.57
Woody invasion	0.39	0.23	0.56	0.14	0.48	-0.34	-0.35
Herbaceous cover	0.51	-0.21	0.05	-0.25	0.15	0.77	-0.13
Vegetation height	0.25	0.33	-0.31	0.77	0.12	0.22	0.26
Height diversity	-0.10	0.66	0.39	-0.32	-0.07	0.22	0.51
Litter depth	0.23	0.19	-0.61	-0.45	0.49	-0.27	0.16
Forb cover	-0.39	-0.42	0.21	0.12	0.64	0.11	0.42

interpreted as a grassland decadence component. The interpretation of PC's 4 and 5 was consistent with their properties of acting in opposition in the multiple regression loadings.

Failure of the predictive capabilities of the model was attributable to similar sources identified for the meadowlark evaluation. These sources included an inadequate range of habitat conditions to provide necessary habitat contrasts for statistical significance, inappropriate measurements for portraying vital habitat characteristics, insufficient data for the model to define the relationships between the species and its habitat, and potential impacts of extended sampling through the growing season. Grasshopper sparrow HSI's were weakly correlated with date ($r = 0.37$, $PR > |R| = 0.0172$).

An additional potential cause of failure might be that the adapted model utilized was inappropriate for the study area. The original models were developed in central Missouri for local grassland conditions. Consequently, since the models were primarily modified in structure and not in biological interpretation, they might not be biologically significant in south central Nebraska. Vegetational regimes likely differ substantially between these areas. Grasslands in central Missouri fall within tallgrass prairie and are influenced by greater annual precipitation. Grasses are more likely to be sod forming than encountered on mixed-grass prairie at the Harlan County Project. Additionally, most pastures in central Missouri likely feature a woodland boundary and greater woody invasion.

While no direct relationships between grasshopper sparrow densities and the model's values (HSI's or SI's) or habitat measurements were detected, there is evidence that construction of an accurate model is feasible. However, measurements suggested in the model do not appear to adequately depict the vital habitat conditions influencing the evaluation species. Principal Components Analysis with multiple regression analysis identifies a potential interaction that the model's habitat measurements indirectly portrayed. Two principal components interpreted as portraying 1) grassland productivity and resistance to retrogression, and 2) extent of retrogression appeared to be related to grasshopper sparrow densities. Thus, there is encouragement that with refinement and further investigation, prediction of grasshopper sparrow abundance, based on vegetative measurements, may be possible. Specific improvements for a grasshopper sparrow model in the mixed grass prairie of Nebraska are easily identified. The model should require measurements indicating the herbaceous foliar cover development of the grassland (foliar volume [Robel Pole], which integrates herbaceous vegetation height with density of herbaceous vegetation). Additionally, the type of grassland, whether the grassland site consists of bunch grass [e.g. warm season natives] or sod forming grasses [e.g. Kentucky bluegrass and brome grasses], should be included.

General HEP Discussion

HEP sampling generated estimates of habitat quality for the 4 evaluation species. However, the reliability and meaning of these results must be considered. HEP is the subject of extensive critical reviews that question the legitimacy of the methodology. The models' simplicity, data bases, construction, and the basic concepts of HEP are questioned.

The models' approach and design may be too simplistic to accurately portray habitat. Matulich et al. (1982) indicated a tendency among wildlife managers to oversimplify evaluation models. Habitat models frequently are constructed around easily measured physical and floristic variables (Farmer et al. 1982). The operational models, which require easily measured factors, may not consider factors that feature more subtle and, potentially, more influential effects on populations (Farmer et al. 1982).

Farmer et al. (1982) indicated that unreliablity of operational models (due to simplicity) might be attributed to model breadth, the number of components addressed (e.g. life requisites for food, reproductive cover, and winter cover), or model depth, the number and kinds of variables used to describe the components (e.g. food life requisite composed of percent canopy cover and canopy height). The evaluation models employed, applied only to limited habitat types and only to limited areas of habitat. Mulé (1982) stated that HEP did not adequately take into account habitat mosaics.

Many studies have indicated that HEP failed to accurately predict animal abundance (Whelan et al. 1979, Darrow et al. 1981, Byrne 1982, Mulè 1982, Lancia et al. 1982). Animal densities are the expression of previous environmental influences regulating birth rates, death rates, or both (Farmer et al. 1982). Furthermore, wildlife populations are subject to limits imposed by the total environment, yet the entire spectrum of variables composing the total environment is never described. Consequently, a direct correspondence between HEP results and population densities is not necessarily going to exist; external factors not considered by an evaluation model may, at any one time, have a greater influence on the species' population. Locally significant factors such as high predator numbers, greater human disruption, greater exposure to elements due to topographical features (e.g. slope, aspect), regular natural phenomenon (seasonal inundation of habitat otherwise appropriate for a ground nesting species) are examples of external controls not considered by a model evaluating general habitat conditions.

Factors other than real changes of habitat quality can influence results of a HEP survey. Whitmore (1979) indicated that birds probably choose relatively constant habitat conditions (e.g. litter depth, basal area) rather than varying conditions (e.g. herbaceous vegetation height which changes during a season) as criteria for habitat selection. The timing of the study within the spring season points out apparrent differences of habitat measurements. Correlation analysis between timing of surveys and

HEP results demonstrated a significant, but weak, positive relationship between date and the grasshopper sparrow HSI and the most influential evaluation variable, percent forb canopy. A weak, negative correlation was detected between date and the vegetative measurement for proportion of the herbaceous canopy that is grass.

The influence that sampling woodlands in July and August rather than in May and June had on evaluation results is unknown. Because forests are somewhat more static in a season (i.e. grasslands proportionately undergo greater development) the impacts of late sampling and chronological differences were probably minimal.

In answer to criticisms that HEP is too simplistic, it is imperative to point out that the models are based on the habitat variables considered valuable, and model results, because of externalities (e.g. local conditions, regional trends), may not be directly related to observed population levels. Furthermore, these externalities may operate over a number of years and only long-term studies may actually reveal the correct relationships. Nonetheless, the values considered are assumed to be the foremost factors detected in previous studies as potentially influencing species population levels. Farmer et al. (1982) indicated that individual studies were often site specific and unrelated. Thus, generalizations concerning habitat model relationships are difficult and subjective decisions during model construction are required to synthesize data.

HEP can be used as a planning tool in resource development (Matulich 1982). However, when used in planning, sufficient detail must be incorporated to accurately depict biological responses from management activities. Farmer et al. (1982) identified model considerations pertinent to the issue of oversimplification of the models. First, a habitat model must have sufficient breadth to encompass instrumental (vital) components. Second, models will not be universally reliable because key habitat components may vary among areas. Models with restricted depth are insensitive to subtle environmental changes. Thus, models can predict increases or decreases in population levels, but not the magnitude of the changes.

In summary, it is recognized that the HEP models are very simplistic and do not necessarily reflect animal abundance at any given time. The models are designed to measure predominant factors that are the foundation of the habitat for the species. It is important to recognize that external factors may supplant the model factors as population limiters in local situations. Consequently, it is the investigator's and land manager's responsibility to be aware of the local interactions.

Numerous authors have challenged the factual bases upon which evaluation models are developed. Very few studies have quantified wildlife-habitat relationships (Mulè 1982), and literature sources frequently do not provide adequate amounts of their data for reliable model construction. Two model considerations identified by Farmer et al. (1982) are that numerous assumptions are required for model construction (particularly if no new habitat data are collected for the modelling effort), and that model assumptions must be clearly stated to permit evaluation of the model's credibility in contributing to land-use decisions. If the limitations of the models are recognized the models may remain functional.

The lack of correlation between HSI's and animal densities may be considered a serious failing of HEP (Byrne 1982). However, nonuse of an area does not imply the habitat is of poor quality. Additionallly, Byrne (1982), in providing examples of a shortcoming of HEP, failed to distinguish between good habitat and frequently used habitat. The 2 concepts are not synonymous. Lancia et al. (1982) indicated that a model's inability to recognize good habitat is a serious fault, but identifying a little used habitat as high quality may not indicate a general weakness. The converse, identifying a habitat with high usage as being low quality also is not necessarily a weakness. A high use area may actually act to reduce the abundance of the species. An area featuring excellent food sources, which attract usage, but lacking protective cover may subject a species to high predation rates. Consequently, this habitat is poor quality in comparison to an optimal condition habitat featuring excellent food sources and protective cover. Some habitat tracts attracting high densities of a species may actually function as a "sink" draining overall numbers. Whitmore (1979) described a situation where reclaimed strip mines in West Virginia created a habitat where more grasshopper sparrows were destroyed than produced.

The value of correlation analyses to test validity of evaluation models is dubious. Most studies do not have sufficient structure to allow a conclusion of cause and effect. Thus, a relationship observed between a unidimensional habitat variable and species abundance could be the result of a shared relationship with an underlying factor. The models' construction and organization implicitly admit to a complex interaction of habitat conditions. Contrarily, the models employ simplistic measures to depict multidimensional characteristics (e.g. herbaceous canopy cover and average height of herbaceous canopy to portray visual obstruction), which result in a correlation analysis for secondary (indirect) relationships. Usage of correlation tests of validity in localized situations is also marred because of inadequate contrasts (as observed in this study). Finally, models are based on few quantitative studies, which frequently measure a limited number of habitat characteristics and test for relationships with univariate statistical tests.

The construction of these models has pointed out shortcomings in the data base concerning habitat preferences of species. Mulè (1982) stated that quantification studies are needed to describe animal-habitat relationships. However, studies need to employ a different approach. Darrow et al. (1981) recommended that future studies should identify areas of high species abundance and then measure habitat characteristics, rather than measuring habitat variables and censusing species abundance. Known areas of traditionally high densities must be detected and sampled to provide more reliable portrayals of species-habitat interactions. However, studies should also identify productivity of a species on study areas to determine the value of the habitat conditions to the overall population; if separate, areas of high production may be more important than areas of high density. Furthermore, studies such as that of Blenden (1982) who identified relationships between arthropod abundance and avian habitat, serve to document indirect relationships, which may benefit model development.

The models in current form are of limited value for local usage. However, at a regional scale where greater contrasts might exist for comparisons, the models probably are functional. This calls into question the validity of the scale of sampling called for by the models. If the models are applied for regional purposes, macroscale processes are being evaluated using microsampling. Thus, spatial values such as homogeneity of the habitat as well as interspersion and juxtaposition may not be considered.

The process of model construction is questioned by Mulé (1982). The use of technicians to construct models further weakens the data base available in the literature because the special insights of a species expert would be lacking. The current procedure of reviewing the designed models by a species expert should reduce some significant errors. However, Mulè recommended that HEP models be constructed by USFWS species experts when possible, and contracted out for those species for which the USFWS has no expert.

The impact of unspecialized technicians on the models is manifested elsewhere as well. Suggested methodologies for data collection for grassland species (specifically the meadowlark model) calls into question the validity of the model's design. The use of the line intercept method to calculate canopy cover is readily applicable for the forester, yet virtually useless for the range manager. The Focal-Point Technique (Burzlaff 1966), the method utilized for herbaceous canopy measurements, was easily applied and provided measurements considered biologically significant to wildlife species. However, the method is not considered by Hays et al. (1981).

Consequently, for those models based on an accurate understanding of the species' life history, the model may still fail because of design and construction by unspecialized technicians. Models should be substantiated by appropriate habitat specialists (range scientists or foresters) as well as evaluation species experts to insure proper design and suggested methodologies.

Methods of calculating HSI's are presented in 2 different ways in USFWS publications discussing HEP. One method, which averaged all habitat measurements prior to application of suitability curves, is presented within an example in ESM 103, Standards for the Development of Habitat Suitability Index Models (USFWS 1981). The methodology of averaging HSI's is demonstrated within ESM 102, Habitat Evaluation Procedures (HEP) (USFWS 1980). The latter methodology was regarded as the superior technique for this study.

Habitat averaging was considered most likely to provide inaccurate HSI's based on the vegetative sampling. Averaging habitat measurements for an entire sample class (grassland group or woodland type) tended to obscure differences between areas within the sample class. For example, measurements of snag densities for the black-capped chickadee and downy woodpecker evaluations yielded high model values according to habitat averaging whereas averaging of site evaluations (HSI) generated lower values. This discrepancy is the result of uneven distribution of densities of snags. For open woodlands very high snag densities were encountered at several evaluation sites and very low densities were encountered at the remainder of the sites. These very high density sites influenced other evaluation sites when habitat averaging was employed. However, when results from each evaluation site were applied to the evaluation models the tremendous impact of the rare, high density sites was reduced.

Another negative aspect of the habitat averaging approach is the inability of the technique to statistically compare HSI's. Only habitat measurements can be tested for significant differences. However, averaging of evaluation sites allows comparisons of HSI's, model variables, and LRV's as well as the habitat measurements.

Finally, for the last critique of HEP to be considered, Byrne (1982) identified the characteristic of HEP of ignoring population levels of species as the most serious drawback of the methodology. While this may be a legitimate criticism of the methodology in mitigation situations, it does not have application to the usage of HEP in this study. Mitigation studies attempt to compare current and future conditions of differing areas for the purposes of insuring remuneration for lost habitat. However, HEP in this study is used to quantify current conditions in relationship to optimal conditions. Despite the many weaknesses exposed by critics, HEP continues to be used. HEP, as previously noted, is widely applied in management situations. It incorporates what is known of a species' natural history in a functional evaluation model. Even critics admit that HEP reduces subjectivity from habitat analysis (Byrne 1982). The benefits of using HEP to anticipate future wildlife values are presented by Urich and Graham (1983) and Rhodes et al. (1983). The methodology, receptive to improvements (Cole and Smith 1983), remains the "state-of-the-art" available to land managers. To dismiss the methodology because abuses may occur is unconstructive. In fact, abuses did occur prior to HEP; HEP standardizes evaluations, thus, abuses may be more easily detected.

In summary, whether HEP is a legitimate methodology in resource management is largely dependent on the user. Reliability of HEP as a predictor of habitat quality is a function of the data available and user's cognizance of the method's strengths and limitations. Seitz et al. (1982) stated that the models are only as important as how they help during the decision making process. Furthermore, Farmer et al. (1982) indicated that although evaluation of something as complex as a species' habitat may be futile, wildlife managers must deal in values, and decisions will be made with the little information available or with no information at all.

CONCLUSIONS

HSI and HEP Models were marginally successful or unsuccessful in yielding quantitative assessments of habitat quality that correlated with estimates of evaluation species densities. Two models were tested for each of the habitats considered: woodland and grassland. The woodland models' weaknesses were primarily attributable to difficulties in interpreting species/habitat relationships and converting these relationships to mathematical functions. Weaknesses of grassland models were similar. Additionally there were fundamental flaws in habitat measurements considered and sampling techniques.

Downy woodpecker densities correlated with Model HSI values ($r = 0.74$). Woodpecker densities tended to follow trends predicted by the evaluation model. Woodpecker density was linearly correlated with snag density ($r = 0.72$) and curvilinearly correlated with basal area ($r = 0.83$). However, the species' habitat requirements and, consequently, the evaluation model were very simplistic.

Black-capped chickadee densities correlated negatively with Food LRV ($r = -0.76$) and SI TWO ($r = -0.88$). Thus, the model incorrectly portrayed the relationships observed on the Harlan County Project. However, correlations between chickadee densities and 2 habitat measurements (canopy cover $r = -0.66$, canopy height $r = -0.83$) revealed that the model recommended appropriate habitat measurements.

Tests of the meadowlark and grasshopper sparrow models failed to detect significant relationships between species densities and model results. However, a relationship between average height of herbaceous canopy, a habitat measurement recommended by the model, and meadowlark densities supported a trend predicted by the model. Although no direct relationships were detected for the grasshopper sparrow, multivariate testing indicated that measurements portraying grassland conditions (litter depth, vegetation height, woody invasion, and forb cover) were indirectly linked with sparrow densities. Failure of these models to perform successfully was attributed to an inadequate range of habitat conditions to provide necessary contrasts, inapropriate measurements recommended by the evaluation models, potential impacts of extended sampling through the growing season, and insufficient data bases to define species/habitat relationships.

Models called for measurements and techniques that were not most efficient or the best descriptor of the habitat condition considered. Furthermore, some models required measurements of vegetation that varied tremendously through the recommended sample season. These flaws revealed that habitat experts should be included in model design and development with evaluation species experts, to insure that meaningful data are collected.

Definition of what constitutes "high quality habitat" was considered difficult. A tract of habitat featuring high densities of a species was not necessarily producing a high number of individuals to future populations. However, most studies of species usage and selection of habitat rely on density estimates. Thus, the premise that HSI values should predict evaluation species densities was not considered entirely appropriate. To construct especially valuable models, the data bases upon which models are created must be improved.

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APPENDICES

APPENDIX A

DOWNY WOODPECKER (Picoides pubescens)

HABITAT USE INFORMATION

General

Downy woodpeckers (Picoides pubescens) inhabit nearly all of North America where trees are found (Bent 1939). They are rare or absent in arid desert habitats and most common in open woodlands.

Food

The downy woodpecker is primarily an insectivore; 76% of the diet is animal foods, and the remainder is vegetable food (Beal 1911). Beetles, ants, and caterpillars are the major animal foods, and vegetable foods include fruits, seeds, and mast. Downy woodpeckers feed by digging into the bark with the bill, by gleaning along the bark surface, and, infrequently, by flycatching (Jackson 1970).

Downy woodpeckers in Illinois foraged more in the lower height zones of trees than in the tree canopies and foraged more often on live limbs than on dead limbs (Williams 1975). Similarly, downy woodpeckers in Virginia foraged primarily on live wood in pole age and mature forests (Conner 1980). Downy woodpeckers in New York spent 60% of their foraging time in elms (Ulmus spp.) (Kisiel 1972). They foraged most frequently on twigs 2.5 cm (1 inch) or less in diameter, and drilling was the foraging technique used most often. Downy woodpeckers are not strong excavators and do not excavate deeply to reach concentrated food sources, such as carpenter ants (Camponotus spp.) (Conner 1981).

Downy woodpeckers in Virginia foraged in the breeding season in habitats with a mean basal area of 11.3 m^2/ha (49.2 ft^2/acre). Habitats used for foraging during the postbreeding and winter seasons had significantly higher mean basal areas of 21.4 m^2/ha (93.2 ft^2/acre) and 17.2 m^2/ha (74.9 ft^2/acre), respectively. Downy woodpeckers in New Hampshire fed heavily in stands of paper birch (Betula papyrifera) that were infected with a coccid (Xylococchus betulae) (Kilham 1970). The most attractive birches for foraging were those that were crooked or leaning, contained broken branches in their crown, and had defects, such as cankers, old wounds, broken branch stubs, and sapsucker drill holes. Downy woodpeckers invaded an area in Colorado in high numbers during the winter months in response to a severe outbreak of the pine bark beetle (Dendroctonus ponderosae) (Crockett and Hansley 1978). This outbreak of beetles had not resulted in increased breeding densities of the woodpeckers at the time of the study.

Downy woodpeckers foraged more on tree surfaces during summer than in winter (Conner 1979). They increased the amount of time spent in subcambial excavation in winter months, probably in response to the seasonal availability and location of insect prey. Downy woodpeckers appear to broaden all aspects of their foraging behavior in the winter in order to find adequate amounts of food (Conner 1981).

Downy woodpeckers in Ontario extracted gall fly (Eurosta solidaginis) larvae from goldenrod (Solidago canadensis) galls growing near forest edges (Schlichter 1978). Corn stubble fields supported small winter populations of downy woodpeckers in Illinois (Graber et al. 1977).

Water

Information on the water requirements of the downy woodpecker was not located in the literature.

Cover

The cover requirements of the downy woodpecker are similar to their reproductive requirements, which are discussed in the following section.

Reproduction

The downy woodpecker is a primary cavity nester that prefers soft snags for nest sites (Evans and Conner 1979). These woodpeckers nest in both coniferous and deciduous forest stands in the Northwest. Nests in Virginia were common in both edge situations and in dense forests far from openings (Conner and Adkisson 1977). Downy woodpeckers in Oregon occur primarily in deciduous stands of aspen (Populus tremuloides) or riparian cottonwood (Populus spp.) (Thomas et al. 1979). The highest nesting and winter densities in Illinois were in virgin or old lowland forests (Graber et al. 1977).

Downy woodpeckers in Virginia preferred to nest in areas with high stem density, but with lower basal area and lower canopy heights than areas used by the other woodpeckers studied (Conner and Adkisson 1977). They preferred sparsely stocked forests commonly found along ridges (Conner et al. 1975). Preferred nest stands had an average basal area of 10.1 m²/ha (44 ft²/acre), 361.8 stems greater than 4 cm (1.6 inches) diameter/ha (894/acre), and canopy heights of 16.3 m (53.5 ft) (Conner and Adkisson 1976). Downy woodpeckers in Tennessee were frequently seen feeding in the understory and apparently selected habitats with an abundance of understory vegetation (Anderson and Shugart 1974).

Downy woodpeckers excavate their own cavity in a branch or stub 2.4 to 15.3 m (8 to 50 ft) above ground, generally in dead or dying wood (Bent 1939). There was a positive correlation between downy woodpecker densities and the number of dead trees in Illinois (Graber et al. 1977). Downy woodpeckers rarely excavate in oaks (Quercus spp.) or hickories (Carya spp.) with living cambium present at the nest site (Conner 1978). They apparently require both sap rot, to soften the outer part of trees, and heart rot, to soften the interior, when hardwoods, and possibly pines, are used for nesting. Downy woodpeckers in Virginia nested mainly in dead snags with advanced stages of fungal heart rot (Conner and Adkisson 1976).

Downy woodpeckers "search image" of an optimal nest site is a live tree with a broken off dead top (Kilham 1974). Suitable nest trees are in short supply in most areas and appear to be a limiting factor in New Hampshire. Downies in Montana appeared to prefer small trees, possibly to avoid the difficulty of excavating through the thick sapwood of large trees (McClelland et al. 1979). The average dbh of nest trees (n = 3) in Montana was 25 cm (10 inches). All 11 nests in an Ontario study were in dead aspen, and the average dbh of four of these nest trees was 26.2 cm (10.3 inches) (Lawrence 1966). Fourteen of 19 nest trees in Virginia were dead, the average dbh of nest trees was 31.8 cm (12.4 inches), and nest trees averaged 8.3 m (27.2 ft) in height (Conner et al. 1975).

Thomas et al. (1979) estimated that downy woodpeckers in Oregon require 7.4 snags, 15.2 cm (6 inches) or more dbh, per ha (3 snags/acre). This estimate is based on a territory size of 4 ha (10 acres), a need for two cavities per year per pair, and the presence of 1 useable snag with a cavity for each 16 snags without a cavity. Evans and Conner (1979) estimated that downies in the Northeast require 9.9 snags, 15 to 25 cm (6 to 10 inches) dbh, per ha (4 snags/acre). Their estimate is based on a territory size of 4 ha (10 acres), a need for four cavity trees per year per pair, and a need for 10 snags for each cavity tree used in order to account for unuseable snags, a reserve of snags, feeding habitat, and a supply of snags for secondary users. Conner (pers. comm.) recommended 12.4 snags/ha (5 snags/acre) for optimal downy woodpecker habitat.

Interspersion

Downy woodpeckers occupy different size territories at different times of the year (Kilham 1974). Fall and winter territories consist of small, defined areas with favorable food supplies and the area near roost holes. Breeding season territories consist of an area as large as 10 to 15 ha (24.7 to 37.1 acres) used to search out nest stubs, and a smaller area around the nest stub itself. Breeding territories of downies in Illinois ranged from 0.5 to 1.2 ha (1.3 to 3.1 acres) (Calef 1953 cited by Graber et al. 1977). Male and female downy woodpeckers retain about the same breeding season territory from year to year, while their larger overall range has more flexible borders (Lawrence 1966).

Downy woodpeckers occupy all portions of their North American breeding range during the winter (Plaza 1978). There is, however, a slight, local southward migration in many areas.

Special Considerations

Conner and Crawford (1974) reported that logging debris in regenerating stands (1-year old) following clear cutting were heavily used by downy woodpeckers as foraging substrate. Timber harvest operations that leave snags and trees with heart rot standing during regeneration cuts and subsequent thinnings will help maintain maximum densities of downy woodpeckers (Conner et al. 1975). Foraging habitat for the downy woodpecker in Virginia would probably be provided by timber rotations of 60 to 80 years (Conner 1980).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for the entire range of the downy woodpecker.

Season. This model was developed to evaluate the year-round habitat needs of the downy woodpecker.

Cover types. This model was developed to evaluate habitat in Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) areas (terminology follows that of U.S. Fish and Wildlife Service 1981).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will live and reproduce in an area. Specific information on minimum habitat areas for downy woodpeckers was not found in the literature. However, based on reported territory and range sizes, it is assumed that a minimum of 4 ha (10 acres) of potentially useable habitat must exist or the HSI will equal zero.

Verification level. Previous drafts of this model were reviewed by Richard Conner and Lawrence Kilham and their comments were incorporated into the current draft (Conner, pers. comm.; Kilham, pers. comm.).

Model Description

Overview. This model considers the ability of the habitat to meet the food and reproductive needs of the downy woodpecker as an indication of overall habitat suitability. Cover needs are assumed to be met by food and reproductive requirements and water is assumed not to be limiting. The food component of this model assesses food quality through measurements of vegetative conditions. The reproductive component of this model assesses the abundance of suitable snags. The relationship between habitat variables, life requisites, cover types, and the HSI for the downy woodpecker is illustrated in Figure 1.

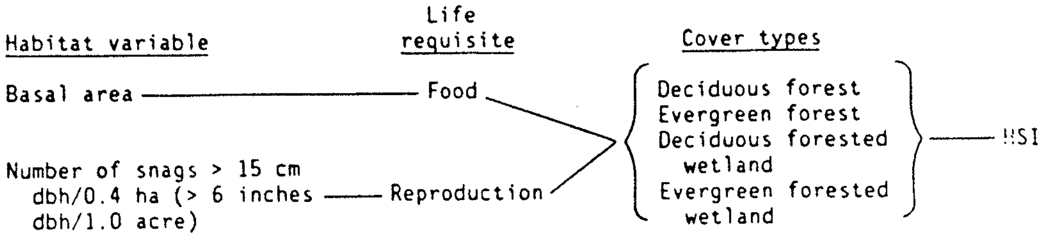


Figure 1. Relationships of habitat variables, life requisites, and cover types in the downy woodpecker model.

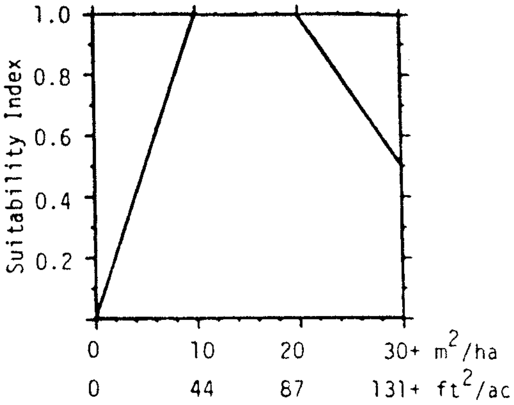
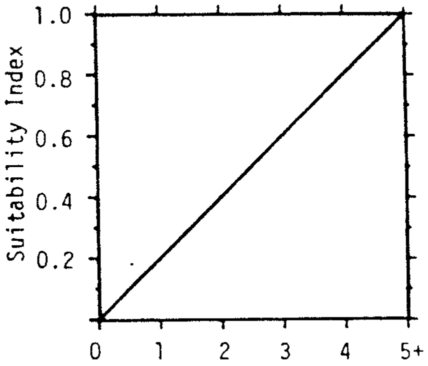
The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the downy woodpecker in order to explain the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food component. Food for the downy woodpecker consists of insects found on trees in forested habitats. Downy woodpeckers occupy a wide variety of forested habitats from virgin bottomlands to sparsely stocked stands along ridges. The highest downy woodpecker densities were most often reported in the more open stands with lower basal areas, but it is assumed that all forested habitats have some food value for downies. Optimal conditions are assumed to occur in stands with basal areas between 10 and 20 m^2/ha (43.6 and 87.2 ft^2/acre), and suitabilities will decrease to zero as basal area approaches zero. Stands with basal areas greater than 30 m^2/ha (130.8 ft^2/acre) are assumed to have moderate value for downy woodpeckers.

Reproduction component. Downy woodpeckers nest in cavities in either totally or partially dead small trees. They require snags greater than 15 cm (6 inches) dbh for nest sites. Optimal habitats are assumed to contain 5 or more snags greater than 15 cm dbh/0.4 ha (6 inches dbh/1.0 acre), and habitats without such snags have no suitability.

Model Relationships

Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable		Suitability graph
EF,DF, EFW,DFW	V_1	Basal area.	
EF,DF, EFW,DFW	V_2	Number of snags > 15 cm dbh/0.4 ha (> 6 inches dbh/ 1.0 acre).	

<u>Life requisite values</u>. The life requisite values for the downy woodpecker are presented below.

Life requisite	Cover type	Life requisite value
Food	EF,DF,EFW,DFW	V_1
Reproduction	EF,DF,EFW,DFW	V_2

HSI determination. The HSI for the downy woodpecker is equal to the lowest life requisite value.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 2.

Variable (definition)		Cover types	Suggested technique
V_1	Basal area [the area of exposed stems of woody vegetation if cut horizontally at 1.4 m (4.5 ft) height, in m^2/ha (ft^2/acre)].	EF,DF,EFW,DFW	Bitterlich method
V_2	Number of snags > 15 cm (6 inches) dbh/0.4 ha (1.0 acre) [the number of standing dead trees or partly dead trees, greater than 15 cm (6 inches) diameter at breast height (1.4 m/4.5 ft), that are at least 1.8 m (6 ft) tall. Trees in which at least 50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags].	EF,DF,EFW,DFW	Quadrat

Figure 2. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

Conner and Adkisson (1976) have developed a discriminant function model for the downy woodpecker that can be used to separate habitats that possibly provide nesting habitat from those that do not provide nesting habitat. The model assesses basal area, number of stems, and canopy height of trees.

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BLACK-CAPPED CHICKADEE (*Parus atricapillus*)

HABITAT USE INFORMATION

General

The black-capped chickadee (*Parus atricapillus*) inhabits wooded areas in the northern United States, Canada, and the higher elevations of mountains in southern Appalachia (Tanner 1952; Brewer 1963; Merritt 1981). The black-capped chickadee nests in cavities in dead or hollow trees (Nickell 1956), in a variety of forest types (Dixon 1961).

Food

Black-capped chickadees are insectivorous gleaners (Brewer 1963; Sturman 1968b) that select prey in proportion to its availability (Brewer 1963). Insect food is mostly gleaned from tree bark on twigs, branches, and boles; or from the foliage, fruits, and flowers of trees (Brewer 1963). Caterpillars are an important food for nestling chickadees (Odum 1942; Kluyver 1961; Sturman 1968a). Insect and spider eggs make up a large portion of the winter diet, and, although the use of plant material for food is low during much of the year, seeds of trees and shrubs may account for about half of the winter diet (Martin et al. 1961). Seeds of weedy plants, such as giant ragweed (*Ambrosia* spp.), are favorite winter foods (Fitch 1958).

Black-capped chickadees are versatile in their foraging habits and forage from the ground to the tree tops in a variety of habitats, although they prefer to forage at low or intermediate heights in trees and shrubs (Odum 1942). Chickadees in British Columbia showed a preference for foraging within 1.5 m (5.0 ft) of the ground (Smith 1967).

Black-capped chickadees in western Washington selected their territories before the amount of insect food (especially caterpillars) was apparent, and it appeared that canopy volume of trees was the proximate cue used by the chickadees to determine potential food supply, since chickadee abundance showed a strong positive correlation with canopy volume (Sturman 1968a). Caterpillars eat foliage and their abundance should vary directly with total foliage weight. There was a strong positive correlation between total foliage weight and canopy volume, and, hence, canopy volume provided a good estimate of potential insect abundance. The highest chickadee densities occurred at canopy volumes of about 10.2 m^3 of foliage/1 m^2 of ground surface (33.5 ft^3/ft^2).

Water

Drinking water requirements are met with surface water and snow (Odum 1942).

Cover

The black-capped chickadee occurs in both deciduous and evergreen forests in the eastern United States, although it is restricted to deciduous forests along streams in the Northern Great Plains, northern Rocky Mountains, and Great Basin areas (Dixon 1961). In some areas where the ranges of the black-capped chickadee and Carolina chickadee (P. carolinensis) come together, apparently suitable habitat exists where neither chickadee occurs (Tanner 1952; Brewer 1963; Merritt 1981). Deciduous forest types are preferred in western Washington (Sturman 1968a) and commonly used in Oregon (Gabrielson and Jewett 1940). Fall and winter roosts in New York were mostly on dense conifer branches, with some use of cavities (Odum 1942). Black-capped chickadees in Oregon and Washington excavated winter roost cavities in snags (Thomas et al. 1979). Winter roosts in deciduous forests of Minnesota were on the branches of trees and bushes that had retained their foliage (Van Gorp and Langager 1974).

Black-capped chickadee populations in Kansas tended to concentrate along edges between forest and early successional areas (Fitch 1958). The availability of suitable tree cavities for roosting may have been a limiting factor in this study area.

Reproduction

The black-capped chickadee nests in a cavity, usually in a dead or hollow tree (Nickell 1956). The presence of available nest sites, or trees that could be excavated, appeared to determine the chickadee's choice of nesting habitat. Two important factors affecting the use of stub trees in Michigan were height and the suitability of the tree for excavation (Brewer 1963). Willows (Salix spp.), pines (Pinus spp.), cottonwoods and poplars (Populus spp.), and fruit trees of the genera Pyrus and Prunus are frequently chosen for nest sites (Brewer 1961).

Black-capped chickadees are only able to excavate a cavity in soft or rotten wood (Odum 1941a, b). Trees with decayed heartwood, but firm sapwood, are usually chosen (Brewer 1961). Black-capped chickadees almost always do some excavation at the nest site (Tyler 1946), although they will use existing woodpecker holes, natural cavities, man-made nest boxes, and open topped fence posts (Nickell 1956). The average tree diameter at nest sites was 11.4 cm (4.5 inches), and preferred tree stubs apparently ranged from 10 to 15 cm (3.9 to 5.9 inches) in diameter (Brewer 1963). The minimum dbh of cavity trees used by black-capped chickadees is 10.2 cm (4 inches) (Thomas et al. 1979). Heights of 18 nests in New York ranged from 0.3 to 12.2 m (1 to 40 ft), although only three nests were higher than 4.6 m (15 ft) and 11 nests were under 3.0 m (10 ft) (Odum 1941b).

Nests in New York were usually located in open areas, commonly in young forests, hedgerows, or field borders (Odum 1941a). Willow, alder (Alnus spp.) and cottonwood trees were common nest trees in Washington (Jewett et al. 1953). Black-capped chickadees used second growth alder for nesting sites in British Columbia (Smith 1967).

Interspersion

Black-capped chickadees maintain a territory during the breeding season and flock in the winter months (Odum 1941b; Stefanski 1967). Territory size during nest building in Utah averaged 2.3 ha (5.8 acres) (Stefanski 1967).

Territory size in New York varied from 3.4 ha to 6.9 ha (8.4 to 17.1 acres), with an average size of 5.3 ha (13.2 acres) (Odum 1941a). The larger territories were in open or sparsely wooded country; the size of the territory decreased as the nesting period progressed. The mean home range size of winter flocks was 9.9 ha (24.4 acres) in Kansas (Fitch 1958), 15.0 ha (37 acres) in Michigan (Brewer 1978), and 14.6 ha (36 acres) in New York (Odum 1942) and in Minnesota (Ritchison 1979).

Black-capped chickadees nesting on forest islands in central New Jersey did not nest in forests less than 2 ha (4.8 acres) in size (Galli et al. 1976). However, this apparent dependency on a minimum size forest may have been due to a lack of nesting cavities.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for the entire breeding range of the black-capped chickadee.

Season. This model was developed to evaluate the breeding season habitat needs of the black-capped chickadee.

Cover types. This model was developed to evaluate habitat in Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) areas (terminology follows that of U.S. Fish and Wildlife Service 1981). It should be noted that, although the chickadee occurs in both deciduous and evergreen forests over much of its range, apparently there are geographic differences in use of cover types that limit the use of evergreen forests in parts of its range. Users should be familiar with the chickadee's major cover type preferences in their particular area before applying this model.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Although Galli et al. (1976) report that black-capped chickadees may be dependent on certain forest sizes, other studies state that these chickadees will nest in hedgerows and field borders. This model assumes that forest size is not an important factor in assessing habitat suitability for the black-capped chickadees.

Verification level. Previous drafts of this model were reviewed by Peter Merritt, and his specific comments have been incorporated into the current draft (Merritt, pers. comm.).

Model Description

Overview. This model considers the ability of the habitat to meet the food and reproductive needs of the black-capped chickadee as an indication of overall habitat suitability. Cover needs are assumed to be met by food and reproductive requirements and water is assumed not to be limiting. The food component of this model assesses vegetation conditions, and the reproduction component assesses the abundance of suitable snags. The relationship between habitat variables, life requisites, cover types, and the HSI for the black-capped chickadee is illustrated in Figure 1.

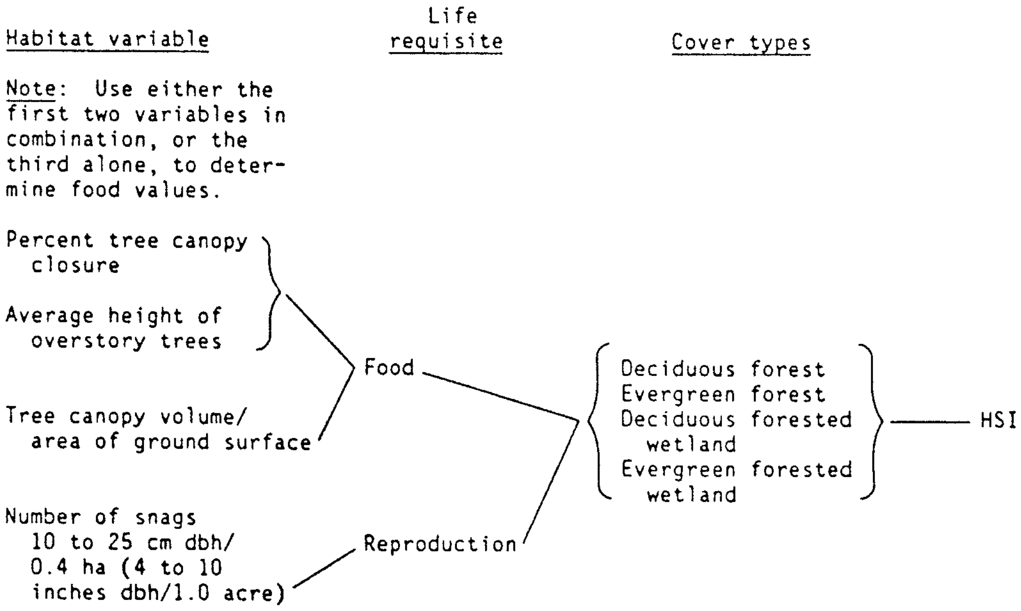


Figure 1. Relationship of habitat variables, life requisites, and cover types in the black-capped chickadee model.

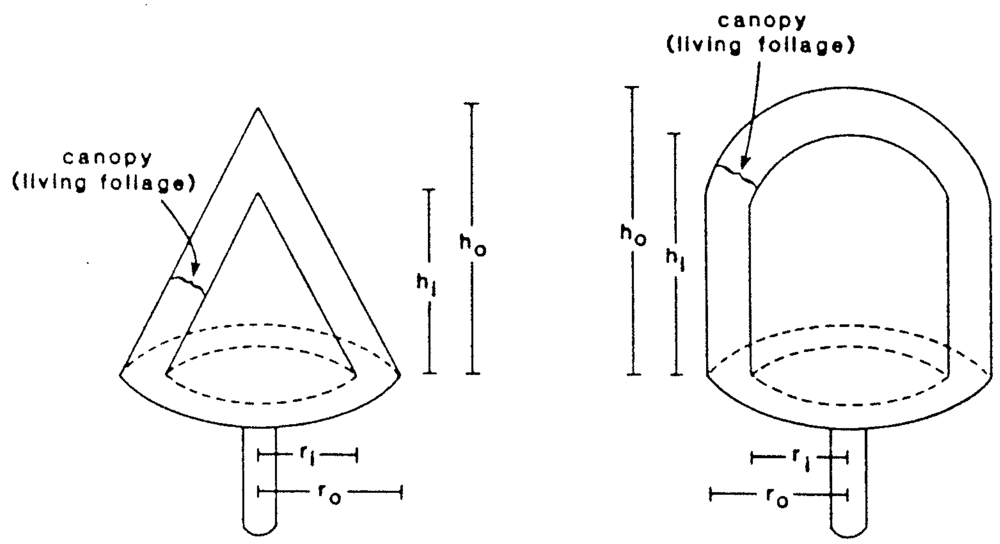
The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the black-capped chickadee in order to explain the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables that will be used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food component. The majority of the year-round food supply of the black-capped chickadee is associated with trees. It is assumed that an accurate assessment of food suitability for the chickadee can be provided by a measure of either: (1) tree canopy closure and the average height of overstory trees; or (2) canopy volume of trees per area of ground surface. It is assumed that optimum canopy closures occur betwen 50 and 75%. A completely closed canopy will have less than optimum value due to an assumed lack of foliage in the middle and lower canopy layers. It is assumed that optimum habitats contain overstory trees 15 m (49.2 ft) or more in height. Habitats with a low canopy closure can provide moderate suitability for black-capped chickadees if tree heights are optimum. Likewise, habitats with short trees may have moderate suitability if canopy closures are optimum.

The canopy volume of an individual tree is equal to the area occupied by the living foliage of that tree, as shown in Figure 2 for deciduous and coniferous trees. Optimum canopy volume per area of ground surface exceeds 10.2 m^3 of foliage/m^2 of ground surface (33.5 ft^3 of foliage/ft^2 of ground surface). Suitability will decrease to zero as canopy volume approaches zero.

The field user should measure either: (1) tree canopy closure and tree height; or (2) tree canopy volume per area of ground surface. Tree canopy closure and tree height measurements are probably the most rapid method to assess food suitability. However, the suitability levels of these variables were not based on strong data sources. The suitability levels of tree canopy volume were based on data from Sturman (1968a).

Reproduction component. Black-capped chickadees nest primarily in small dead or hollow trees and can only excavate a cavity in soft or rotten wood. Therefore, reproduction suitability is assumed to be related to the abundance of small snags. It is assumed that snags between 10 and 25 cm (4 and 10 inches) dbh are required. Thomas et al. (1979) and Evans and Conner (1979) provide methods to estimate the number of snags required for cavity nesting birds. Assuming a territory size of 2.4 ha (6.0 acres) and a need for one cavity per year per chickadee pair, the method of Thomas et al. (1979) estimates that optimum habitats provide 5.9 snags/ha (2.4/acre), and the method of Evans and Conner (1979) estimates that 4.1 snags are needed per ha (1.67/acre) to provide optimum conditions. This model assumes that optimum suitability exists when there are five or more snags of the proper size per ha (2/acre), and that suitability will decrease to zero as the number of snags approaches zero.



CONIFEROUS

$CV = \pi/3(h_o r_o^2 - h_i r_i^2)$

DECIDUOUS

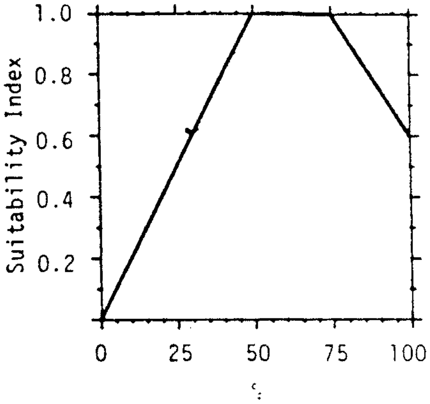
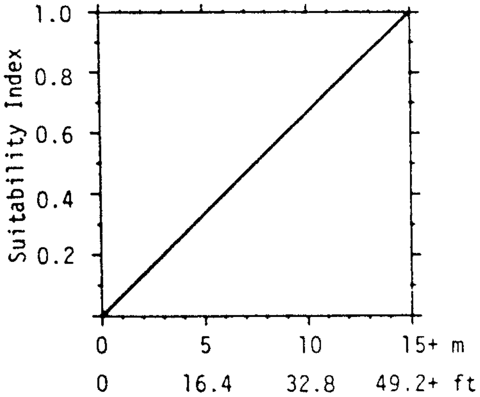
$CV = 2\pi/3(h_o r_o^2 - h_i r_i^2)$

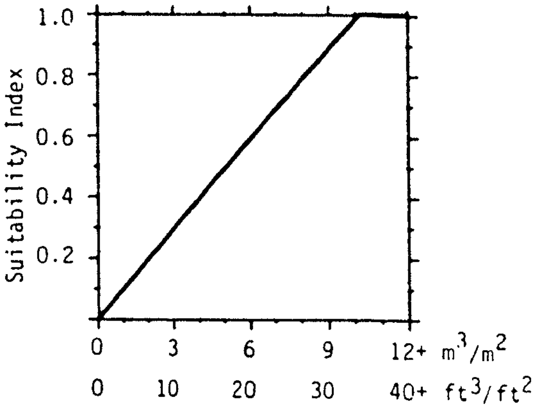
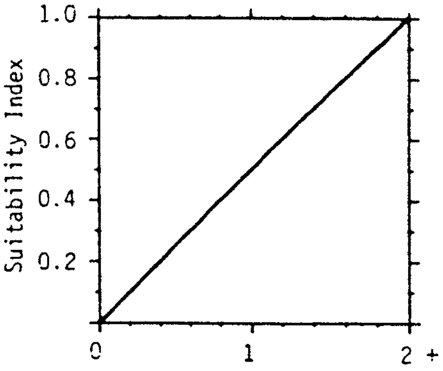
where: h_i = inner height
h_o = outer height
r_i = inner radius
r_o = outer radius

Figure 2. Tree shapes assumed and formulae used to calculate canopy volume (CV). (From Sturman 1968a).

Model Relationships

<u>Suitability Index (SI) graphs for habitat variables</u>. This section contains SI graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable		Suitability graph
DF, EF, DFW, EFW	V_1	Percent tree canopy closure.	
DF, EF, DFW, EFW	V_2	Average height of overstory trees.	

DF,EF, DFW,EFW	V_3	Tree canopy volume/ area of ground surface.	
DF,EF, DFW,EFW	V_4	Number of snags 10 to 25 cm dbh/ 0.4 ha (4 to 10 inches dbh/1.0 acre).	

Equations. In order to determine life requisite values for the black-capped chickadee, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description, and the specific equations in this model were chosen to mimic these perceived biological relationships as closely as possible. The suggested equations for obtaining food and reproduction values are presented below.

Life requisite	Cover type	Equation
Food	DF,EF,DFW,EFW	$(V_1 \times V_2)^{1/2}$ or V_3 (See page 5 for discussion on which to use)
Reproduction	DF,EF,DFW,EFW	V_4

HSI determination. The HSI for the black-capped chickadee is equal to the lowest life requisite value.

Application of the Model

Definitions of variables and suggested field measurement techniques (from Hays et al. 1981, unless otherwise noted) are provided in Figure 3.

Variable (definition)		Cover types	Suggested technique
V_1	Percent tree canopy closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation taller than 5.0 m (16.5 ft)].	DF,EF,DFW,EFW	Line intercept
V_2	Average height of overstory trees (the average height from the ground surface to the top of those trees which are ≥ 80 percent of the height of the tallest tree in the stand).	DF,EF,DFW,EFW	Graduated rod, trigonometric hypsometry
V_3	Tree canopy volume/area of ground surface (the sum of the volume of the canopies of each tree sampled divided by the total area sampled).	DF,EF,DFW,EFW	Quadrat and refer to Figure 2 on page 6

Figure 3. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover types	Suggested technique
V_4	Number of snags 10 to 25 cm dbh/0.4 ha (4 to 10 inches dbh/1.0 acre) [the number of standing dead trees or partly dead trees in the size class indicated that are at least 1.8 m (6 ft) tall. Trees in which at least 50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags].	DF,EF,DFW,EFW	Quadrat

Figure 3. (concluded).

SOURCES OF OTHER MODELS

Sturman (1968a) developed a multiple regression model for the black-capped chickadee in western Washington in which the canopy volume of trees accounted for 79.6% of the variation in chickadee abundance. Canopy volume of bushes and canopy volume of midstory trees were the next two most important variables, and their addition into the regression accounted for over half of the residual variation remaining after the canopy volume of trees was entered.

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EASTERN MEADOWLARK (Sturnella magna)

HABITAT USE INFORMATION

General

The eastern meadowlark (Sturnella magna) is an omnivorous ground feeder (Willson 1974) that nests in open fields throughout the eastern and south-central United States (Robbins et al. 1966).

Food

Approximately 74% of the annual diet consists of animal matter and includes mainly beetles, grasshoppers, caterpillars, and occasionally flies, wasps, and spiders (Beal 1926, cited by Gross 1958). Crickets and grasshoppers comprise 26% of the annual diet, and beetles make up 25% of the annual diet. The remainder of the diet consists of vegetable matter, mainly grain and weed seeds. Seeds of smartweed (Polygonum spp.), ragweed (Ambrosia spp.), corn, wheat, rye, and oats are eaten in the winter months when insects are scarce (Gross 1958). Fruits, such as wild cherries (Prunus spp.), strawberries (Fragaria spp.), and blackberries (Rubus spp.), may also constitute a small percentage of the diet. During adverse winter weather, eastern meadowlarks have been observed to feed on road kills (Hubbard and Hubbard 1969).

Water

No data on drinking water requirements for the eastern meadowlark were located in the literature, although captive eastern meadowlarks do bathe in and drink free water (Gross 1958).

Cover

The eastern meadowlark is primarily found in grasslands, meadows, and pastures (Gross 1958). Meadowlarks inhabited old field successional stages in Georgia from 1 (grass-forb) to 15 years (grass-shrub) after the fields were no longer farmed (Johnston and Odum 1956). This species inhabited fields where shrub coverage was less than 35%, regardless of grass cover in the area. Feeding and loafing cover areas in Missouri that had high use were characterized as grasslands with no forbs or scattered forbs present, while areas where forbs were dominant had little use (Skinner 1975). Maximum use was observed in grazed grasslands between 10 and 30 cm tall (4 and 12 inches), with scattered forbs present.

Reproduction

The preferred nesting habitat of the eastern meadowlark in Illinois was pasture, followed in descending order by hayfields, soilbank fields, winter wheat fields, idle areas, and fallow areas (Roseberry and Klimstra 1970). The density of nesting meadowlarks in pastures was inversely related to the intensity of grazing. Highest nesting densities occurred during the 2 years when pastures were not grazed, and numerous dead grass stems and vigorous stands of grass (fescue) were present. Nesting densities in haylands were highest in a mixed-grass hayfield. Use of alfalfa fields, wheat fields, and fallow areas for nesting was low because these areas lacked sufficient grassy cover to provide suitable nesting habitat. Idle areas were little used when shrubs and trees became abundant. The average height of nesting cover was 38 cm (15 inches), with the majority of nests located in cover 25 to 50 cm (10 to 20 inches) high. The presence of dead grass stems at ground level and the absence of woody vegetation or numerous shrubs in the immediate vicinity of the nest site seemed necessary for nesting.

Nests of the eastern meadowlark are built in shallow depressions and have a dome-shaped roof constructed of grass, frequently interwoven with clumps of grasses or weeds (Gross 1958). Elevated singing and lookout perches, such as telephone wires, electric power lines, mounds of earth, farm implements, or fence posts, are used by males.

Interspersion

Meadowlark territories in Wisconsin varied in size from 1.2 to 6.1 ha (3 to 15 acres) and were commonly 2.8 to 3.2 ha (7 to 8 acres) (Lanyon 1956). The average size of 15 territories in New York was 2.8 ha (7 acres) (Gross 1958).

Special Considerations

Domestic cats and dogs prey on the eggs and young of the eastern meadowlark, and close proximity of nesting sites to human habitations is undesirable (Lanyon 1957). Mowing and heavy grazing by livestock may destroy meadowlark nests (Roseberry and Klimstra 1970).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within the breeding range of the eastern meadowlark.

Season. This model was developed to evaluate the breeding season habitat of the eastern meadowlark.

Cover types. This model was developed to evaluate habitat quality in the following cover types: Pasture and Hayland (P/H); Grassland (G); and Forbland (F) (terminology follows that of U.S. Fish and Wildlife Service 1981).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will occupy an area. Specific information on minimum areas required for eastern meadowlarks was not found in the literature. Based on home range data, it is assumed that a minimum of 1.2 ha (3.0 acres) of habitat must exist or the HSI will equal zero.

Verification level. Previous drafts of this model were reviewed by Fred Alsop, and his specific comments were incorporated into the current draft (Alsop, pers. comm.).

Model Description

Overview. This model considers the feeding and reproductive needs of the eastern meadowlark to determine overall habitat quality and assumes that these two life requisites can be combined to assess habitat. It is assumed that cover needs are met by the feeding and reproductive habitat needs and that water will not be a limiting factor. All of the life requirements of the eastern meadowlark can be provided within each cover type in which it occurs.

The relationship between habitat variables, life requisites, cover types, and the HSI for the eastern meadowlark is illustrated in Figure 1.

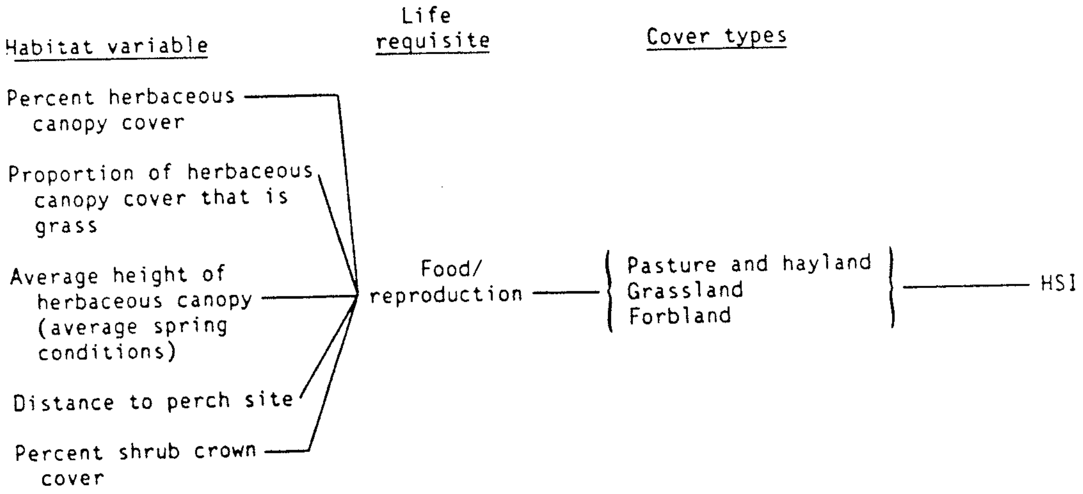


Figure 1. Relationships of habitat variables, life requisites, and cover types in the eastern meadowlark model.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the eastern meadowlark in order to explain and justify the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables that will be used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food/reproduction component. Feeding and reproductive habitat suitability for the eastern meadowlark is related to the height and density of herbaceous vegetation, the abundance of grasses, the presence of shrubs, and the proximity of perch sites. Optimal habitats occur in herbaceous cover types dominated by grasses of moderate heights with low shrub densities and adequate numbers of perches. Meadowlarks prefer very dense vegetation, and optimal herbaceous densities are assumed to occur at greater than 90% canopy cover. Suitability will decrease as the total herbaceous canopy cover decreases, and habitats will not be suitable at canopy covers of less than 20%. Data in the literature indicate that the best habitats are in grasslands with few forbs and that meadowlarks avoid areas where forbs are predominant. It is assumed that optimal conditions will exist when greater than 80% of the herbaceous cover is grass, that suitability will decrease as the relative percent of grass decreases, and that the habitat will not be suitable when less than 20% of the herbaceous cover is grass.

Data in the literature indicate that ideal vegetative heights for foraging and loafing are between approximately 10 and 30 cm (4 and 12 inches) and that the best heights for nesting are between 25 and 50 cm (10 and 20 inches). It is assumed that a large majority of the habitat should be suitable for foraging and loafing to have optimal habitat conditions. Therefore, it is assumed that the best habitats will have an average spring season canopy height of between 12.5 and 35 cm (5 and 14 inches). It is assumed that there will be enough variation in the actual canopy height so that there is a high likelihood of both suitable feeding and nesting heights being present if the average height falls within the range indicated. It is further assumed that, if the average height is less than 2.5 cm (1.0 inches) or greater than 76 cm (30 inches), no suitability will exist.

Ideal meadowlark habitats contain an abundance of perch sites, such as tall forbs, shrubs, trees, fences, or telephone wires. These perches can be within the cover type or on the periphery, such as a forest edge. It is assumed that optimal conditions exist when the average distance from random points in the cover type being evaluated to a suitable perch is less than 30 m (100 ft). This is equivalent to about four perches per 1.2 ha (3.0 acres), the minimum habitat area for the eastern meadowlark. It is assumed that suitability will decrease as the distance to perch sites increases to 60 m (200 ft), which is equal to about one perch site per 1.2 ha (3.0 acres). Some habitat suitability may exist even when there are no apparent perch sites, because of the adaptability of the meadowlark in selecting perches.

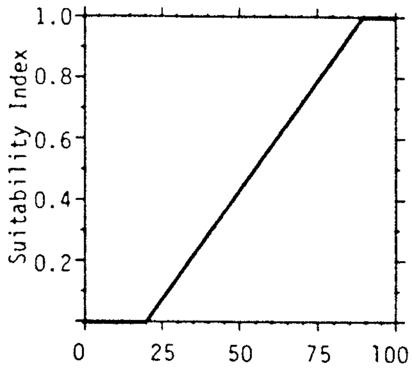
Suitability of the herbaceous component of the habitat is related to the total herbaceous cover, the relative grass cover, the height of herbaceous vegetation, and the proximity of perch sites. It is assumed that each variable exerts a major influence on overall habitat suitability. A habitat must contain optimal levels of all variables to have maximum suitability. Low values of any one variable may be partially offset by higher values of the remaining variables. Habitats with low values for two or more of these variables will have low suitability levels.

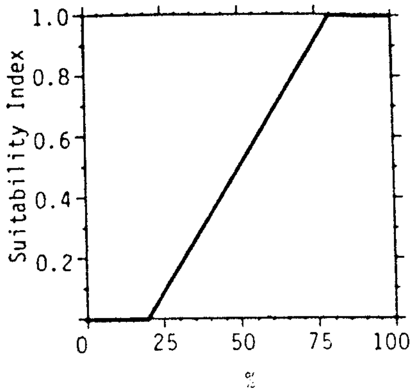
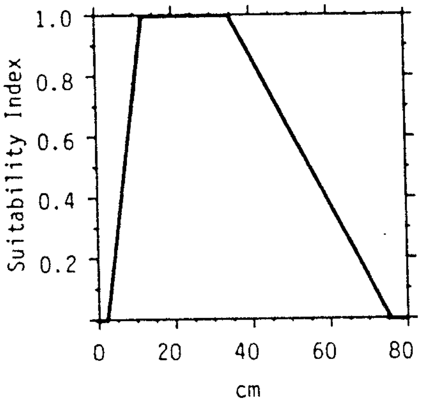
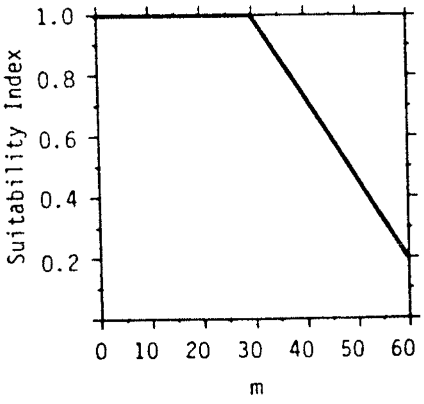
The presence of a moderate or dense shrub cover is a negative influence in meadowlark habitat selection. Optimal habitats contain less than 5% shrub canopy; suitability will decrease as shrub densities increase, and habitat will not be suitable at shrub densities greater than 35%.

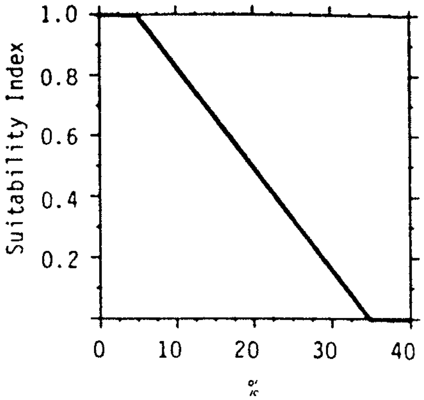
Overall habitat suitability is related to the quality of the herbaceous component described above and the abundance of shrubs. It is assumed that, as shrub densities increase above 5%, the overall habitat value will decrease, regardless of the quality of the herbaceous component.

Model Relationships

Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover Type	Variable		
P/H,G, F	V_1	Percent herbaceous canopy cover.	

P/H,G, F	V_2	Proportion of herbaceous canopy cover that is grass.	
P/H, G, F	V_3	Average height of herbaceous canopy (average spring conditions).	
P/H,G, F	V_4	Distance to perch site (such as tall forb, shrub, tree, fence, or telephone wires).	

P/H,G, F	V_5	Percent shrub crown cover.	

Equations. In order to determine life requisite values for the eastern meadowlark, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description, and the specific equation in this model was chosen to mimic these perceived biological relationships as closely as possible. The suggested equation for obtaining the food/reproduction value is presented below.

Life requisite	Cover type	Equation
Food/Reproduction	P/H,G,F	$(V_1 \times V_2 \times V_3 \times V_4)^{1/2} \times V_5$

HSI determination. The HSI for the eastern meadowlark is equal to the life requisite value for food/reproduction.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 2.

Variable (definition)		Cover types	Suggested techniques
V_1	Percent herbaceous canopy cover (the percent of the ground that is shaded by a vertical projection of all nonwoody vegetation).	P/H,G,F	Line intercept
V_2	Proportion of herbaceous canopy cover that is grass (the relative percent of all herbaceous cover that is comprised of grasses).	P/H,G,F	Line intercept
V_3	Average height of herbaceous canopy (average spring conditions) (the average vertical distance from the ground surface to the dominant height stratum of the herbaceous vegetative canopy during average spring conditions).	P/H,G,F	Line intercept, graduated rod
V_4	Distance to perch site (such as tall forb, shrub, tree, fence, or telephone wires) (the average distance from random points to the nearest suitable perch site, within or outside the boundaries of the cover type).	P/H,G,F	Pacing
V_5	Percent shrub crown cover (the percent of the ground that is shaded by a vertical projection of the canopies of woody vegetation less than 5 m (16.5 ft) in height).	P/H,G,F	Line intercept

Figure 2. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

No other habitat models for the eastern meadowlark were identified.

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A HANDBOOK FOR TERRESTRIAL HABITAT EVALUATION IN CENTRAL MISSOURI

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GRASSHOPPER SPARROW

(Ammodramus savannarum)

Life Requirements

General Habitat

The grasshopper sparrow is a fairly common summer resident in Missouri; it is most abundant in the prairie and Ozark border region (Widmann 1907:177; Bennitt 1932:62-63). Moderately to heavily grazed prairie is used by this sparrow in Missouri (Skinner 1975). Cultivated grasslands of orchard grass, alfalfa, or red clover are favored breeding areas throughout the range (Smith 1963). Sparrows in Georgia use old fields dominated by sparse herbaceous growth but with little shrub coverage (Johnston and Odum 1956). Grasshopper sparrows breed in natural clearings and sparsely wooded areas in Minnesota and Michigan (Roberts 1936:387; Walkinshaw 1940). In Pennsylvania grasslands managed in ways that prevent woody invasion are preferred habitat (Smith 1963).

Cover

Grassy areas with abundant small forbs and moderate to sparse grass densities are preferred cover (Johnston and Odum 1956; Shugart and James 1973). Grazing of grasslands in Missouri creates an interspersion of grass heights, providing both foraging areas and nesting sites (Skinner 1975). Some suitable cover in Arkansas is produced when fields are mowed, or grassy areas burned (Shugart and James 1973). Throughout their range, grasshopper sparrows avoid dense grass (Smith 1963; Shugart and James 1973; Skinner 1975).

Food and Water

Grasshopper sparrows generally forage in open areas within 5 cm of the ground (Wiens 1969:69, 1973). Insects, especially grasshoppers and their nymphs, are eaten in summer. In fall and winter, sparrows prefer seeds of waste grains and grasses (Judd 1901:63). Most of the water required by grasshopper sparrows is obtained from insect food. Some free water may be needed since birds in Kansas were observed near streams off their territories (W.R. Eddleman, personal observation).

Breeding and Nesting

Nests are built in partially open sites under clumps of litter or grass. Total litter is low and forb densities and heights are high in the vicinity of grasshopper sparrow nests (Wiens 1969:76-77). The nest, usually concealed by a dome of stems and blades of grasses, is lined with fine grass and rootlets (Smith 1968).

Males require song perches in their territories. Song perches may be heavy-stemmed forbs, shrubs, fences, posts or utility wires (Smith 1963; Wiens 1969:72).

Land Management

Grassland management has varied effects on habitat of grasshopper sparrows. Haying reduces grass height, but exposes nests to predators and weather (Smith 1963). Moderate grazing results in high grasshopper densities in Missouri (Skinner 1975). Burning of prairies maintains grassland habitat, but may stimulate plant growth, producing grass stands too dense for grasshopper sparrows. Nest sites and nesting material may be temporarily eliminated by fire (Eddleman 1974).

Important Foods of Grasshopper Sparrow

(Listings reflect relative order of importance.)

Animal

Short-horned grasshoppers
Long-horned grasshoppers
Caterpillars
Click beetles
Ground beetles
Weevils
Leaf beetles
Ants
Dung beetles
Spiders
Snails

Plant (seeds)

Waste grains
Wood sorrel
Giant ragweed
Foxtails
Panic grasses
Smartweeds
Purslane
Plantains

Evaluation Element: GRASSHOPPER SPARROW

Habitat Type: GRASSLAND

CHARACTERISTIC	POSSIBLE SCORE	ACTUAL SCORE
I. Average height of vegetation (cm)		I._______
1. 10-19.9	9-10	
2. 2- 9.9; or 20-30	3- 8	
3. Less than 2, or more than 30	1- 2	
(NOTE: If average height of vegetation in characteristic I is less than 5 cm, enter 1 for characteristic II and go directly to III.)		
II. Diversity of vegetation heights		II._______
1. Not uniform: height of less than 50% of vegetation within 5 cm of average height	4- 5	
2. Uniform: height of more than 50% of vegetation within 5 cm of average height	1- 3	
III. Shade-producing woody invasion (average number of trees and clumps of shrubs per 50 m^2)		III._______
1. Less than 3	8-10	
2. 3-6	3- 7	
3. More than 6	1- 2	
IV. Litter depth (cm)		IV._______
1. 0.5-1.5	4- 5	
2. Less than 0.5, or more than 1.5	1- 3	
V. Forb canopy		V._______
1. Covers 10-25% of the ground	5	
2. Covers 26-50% of the ground	3- 4	
3. Covers less than 10% or more than 50% of the ground	1- 2	
<u>To Be Evaluated from Aerial Photographs</u>		
VI. Distance to water (km)		VI._______
1. Less than 0.25	5	
2. 0.25-0.50	3- 4	
3. More than 0.50	1- 2	

Habitat Type: GRASSLAND

Evaluation Element: GRASSHOPPER SPARROW

NOTES: (A) IF CHARACTERISTIC NOT APPLICABLE, ENTER NA AND DO NOT COUNT IT AS A CHARACTERISTIC USED.

(B) IF ALL CHARACTERISTICS ARE SCORED AS 1, DISREGARD COMPUTATIONS BELOW, AND ENTER 1 ON LINE (5) AS HABITAT UNIT VALUE.

---

(1) Maximum possible score for form .... (1) 40

(2) Total maximum possible score(s) for characteristic(s) tallied as NA .... (2) ________

(3) Corrected maximum possible score: (1) - (2) .... (3) ________

(4) Total actual scores .... (4) ________

(5) (4) ÷ (3) x 10 .... (5) ________ HABITAT UNIT VALUE

A Handbook For Habitat Evaluation In Missouri

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1983

Evaluation Element: GRASSHOPPER SPARROW

Habitat Type: PASTURE/HAYLAND

CHARACTERISTIC	POSSIBLE SCORE	ACTUAL SCORE
I. Average Height of Herbaceous Vegetation (inches) (May 1 - July 1)		I. ______
1. 8-12"	8-10	
2. 4-8" or 12-16"	4- 7	
3. 2-4"	2- 3	
4. Less than 2" or more than 16"	1	
(NOTE: If characteristic I is scored as 1, disregard other criteria and enter .1 as Habitat Type Suitability Index.)		
II. Woody Invasion (% of field occuring as woody--trees, shrubs, and vines)		II. ______
1. Zero	10	
2. 1 - 5%	7- 9	
3. 5 - 10%	4- 6	
4. 10-15%	2- 3	
5. More than 15%	1	
(NOTE: If characteristic II is scored as 1, disregard other criteria and enter .1 as Habitat Type Suitability Index.)		
III. Diversity of Vegetation Height		III. ______
1. Not uniform: height of less than 50% of vegetation within 2" of average height	5	
2. Uniform: height of more than 50% of vegetation within 2" of average height	1	
IV. Litter Depth (inches)		IV. ______
1. .2-.6"	3- 5	
2. Less than .2" or more than .6"	1- 2	
V. Forb Canopy Coverage (%)		V. ______
1. 10-25%	5	
2. 25-50%	2- 4	
3. Less than 10% or more than 50%	1	
VI. Herbaceous Canopy Coverage (% grasses and forbs)		VI. ______
1. More than 95%	8-10	
2. 85-95%	4- 7	
3. Less than 85%	1- 3	
VII. Distance to Permanent Water		VII. ______
1. Less than 1/8 mile	5	
2. 1/8 - 1/4 mile	2- 4	
3. More than 1/4 mile	1	

Habitat Type: PASTURE/HAYLAND

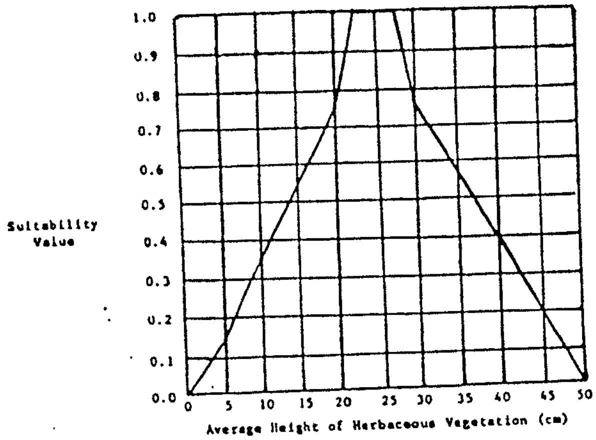
Evaluation Element: GRASSHOPPER SPARROW

CHARACTERISTIC	POSSIBLE SCORE	ACTUAL SCORE
VIII. Field Size (% of field within 660 feet of forest, woodlot, treeline, or shelterbelt)		VIII. ______
1. Less than 10%	9-10	
2. 10-25%	7- 8	
3. 25-50%	5- 6	
4. 50-75%	3- 4	
5. More than 75%	1- 2	

$$\frac{\text{Total Actual Score}}{\text{Maximum Potential Score (60)}} = \text{Habitat Type Suitability Index}$$

Grasshopper Sparrow: Habitat Evaluation Model adapted for the Harlan County Project.

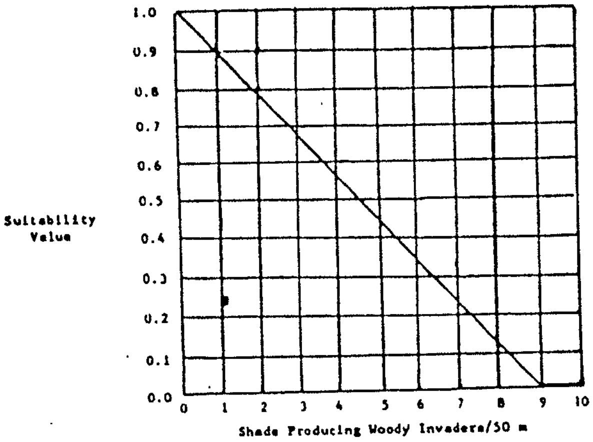
V_1 Average height of herbaceous vegetation (cm).



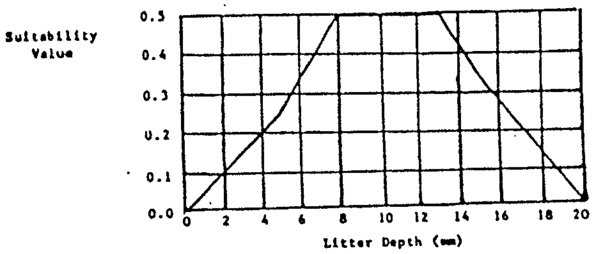
V_2 Diversity of vegetation heights.

1. Not uniform: height of less than 50% of vegetation within 5 cm of average height. 0.5
2. Uniform: height of more than 50% of vegetation within 5 cm of average height. 0.0

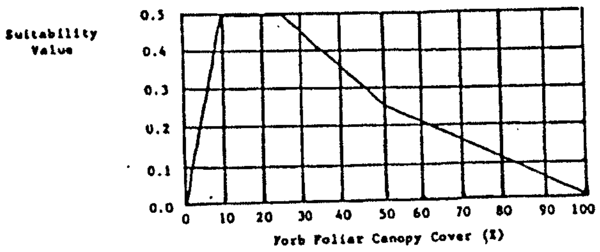
V_3 Shade producing woody invaders/50 m^2.



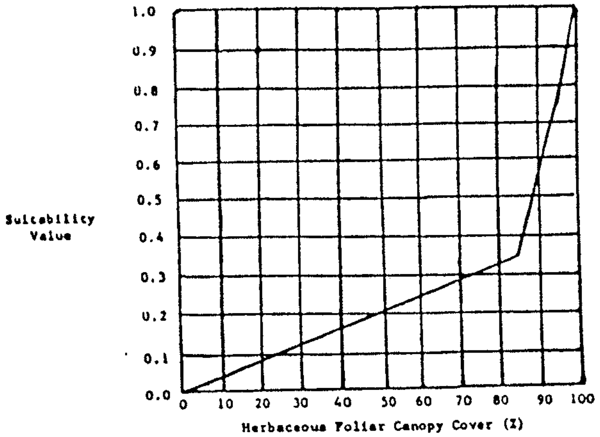
V_4 Litter depth (mm).



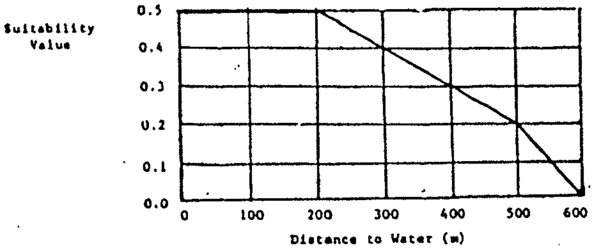
V_5 Forb foliar canopy cover (%).



V_6 Herbaceous foliar canopy cover (%).



V_7 Distance to water (m)



$$HSI = \frac{V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7}{5.0}$$

APPENDIX B

Table 1. Scientific names of plants discussed in report. Organization and nomenclature follows Nebraska Statewide Arboretum (1980) unless otherwise noted.

PLANTS

Big bluestem	*Andropogon gerardi*
Smooth brome	*Bromus inermis*
Downy Brome	*Bromus tectorum*
Buffalograss	*Buchloe dactyloides*
Switchgrass	*Panicum virgatum*
Kentucky bluegrass	*Poa pratensis*
Little bluestem	*Schizachyrium scoparium*
Small soapweed (Yucca)	*Yucca gluaca*
Western ragweed	*Ambrosia psilostachya*
Mullein	*Verbascum* spp.
Box elder	*Acer negundo*
Hackberry	*Celtis occidentalis*
Green ash	*Fraxinus pennsylvanica*
Black walnut	*Juglans nigra*
Eastern redcedar	*Juniperus virginiana*
Red mulberry	*Morus rubra*
Pine	*Pinus* spp.
Eastern cottonwood	*Populus deltoides*
Bur oak	*Quercus macrocarpa*
Willow	*Salix* spp.
American elm	*Ulmus americana*

Table 2. Scientific names of avifauna identified in report. Organization follows AOU (1982).

Downy woodpecker	*Picoides pubescens*
Black-capped chickadee	*Parus atricapillus*
Grasshopper sparrow	*Ammodramus savannarum*
Meadowlark	*Sturnella* spp.
Eastern meadowlark	*Sturnella magna*
Western meadowlark	*Sturnella neglecta*