AN ABSTRACT OF THE THESIS OF

Craig L. Romary for the Master of Science

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Title: Evaluation of the Habitat Suitability Index Models for the Black-capped Chickadee and Downy Woodpecker

Abstract approved: Carl W. Prophet

Habitat Suitability Index (HSI) models for the black-capped chickadee (Parus atricapillus) and downy woodpecker (Picoides pubescens) were used to evaluate the model's abilities in predicting species response to habitat disturbances. HSI models identify habitat variables assumed to limit the success or occurrence of a species. After quantifying these habitat variables, a measure of species response was compared with the model output to determine the relationship between habitat and species abundance. Avian censuses and habitat sampling techniques were conducted at 25 impact and 25 control sites to evaluate the effects of stream channelization on the populations of the black-capped chickadee and downy woodpecker. Censuses were conducted between 1 June and 11 July, 1988. Habitat sampling was conducted between 31 May and 31 September, 1988.

Variables representing the food component of the chickadee model are the average height of the overstory and percent canopy cover. Snag availability represents the reproduction component of the model. No relationship was found between black-capped chickadee densities and the HSI ($r = -0.01$, $P > 0.5$). The lack of relationship between HSI and chickadee densities was largely due to the ineffectiveness of the sampling technique used to estimate the reproduction component of the model. However, the food component of the black-capped chickadee model was able to closely predict the upper limits of species response ($r = 0.93, P < 0.005$). These results suggest that the assumptions concerning the positive correlation between chickadee densities and canopy volume were valid.

Black-capped chickadee densities ($P = 0.06$) and habitat units ($P = 0.08$) were found to be higher at control sites than at impact sites. It appears that these channelization projects do affect the populations of the black-capped chickadee. Continued review of future channelization projects is suggested to minimize the extent of channelization and the amount of riparian vegetation removed.

Variables for the downy woodpecker are basal area and snag availability, representing the food and reproduction components, respectively. Downy woodpecker densities showed no relationship with model output values. The method of sampling snags was not adequate in estimating snag availability. The amount of time and area used in the censusing procedure did not allow adequate detection of the downy woodpecker because of its larger home range.

EVALUATION OF THE HABITAT SUITABILITY INDEX MODELS FOR THE BLACK-CAPPED CHICKADEE AND DOWNY WOODPECKER

A Thesis

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Craig L. Romary

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R. J. Sokol Ph.D.
Approved for Major Department

James L. Wolfe
Approved for Graduate Council

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INTRODUCTION

Riparian areas receive proportionately more use by humans per unit area than any other habitat type, causing conflicts between users of timber, cattle, recreation, water, agricultural land, and wildlife resources (Carothers and Johnson 1975, Davis 1977, Thomas et al. 1979). Characteristics of riparian zones are: 1.) they are well-defined habitat zones within the much drier surrounding area; 2.) they are usually more productive than surrounding habitats in terms of both plant and animal biomass; 3.) they add a critical source of diversity; and 4.) they make up a small portion of the overall area (Thomas et al. 1979). This habitat is composed of an aggregation of plant species which depend on a flow of water on or near the surface for subsistence (Davis 1977).

Besides human uses, riparian habitats are critical to wildlife, especially in regions of intensive agriculture (Stauffer and Best 1980). These habitats provide natural highways or riparian fingers by which wildlife can travel safely from one area to another (Hirsch and Segelquist 1978, Odum 1978, Thomas et al. 1979). Birds are no exception to this attraction. For a given amount of habitat, riparian areas support higher bird densities than any other forest habitat type (Carothers 1977). Fifty-one percent of the Great Plains birds are woodland or forest species, even though these plant communities occupy only about 15 percent of the surface area (Tubbs 1980). Johnston (1964) reported

58 percent of the birds of Kansas to be associated with woodland habitats and listed 21 species of eastern deciduous forest birds which occur in western Kansas only along river drainages. Rising (1974) noted that most of the breeding birds in western Kansas could be classified as woodland species. The presence of these woodland birds is almost completely due to the existence of riparian habitat (Tubbs 1980).

Activities such as stream channelization and the replacement of old and obsolete bridges have often resulted in the destruction of riparian habitat in eastern Kansas. The Environmental Services Section of the Kansas Department of Wildlife and Parks is responsible for assessing the possible environmental impacts of such construction and for developing mitigation plans to offset potential fish and wildlife losses. In the past, the evaluation of these potential impacts has been conducted mainly on a subjective basis (Dr. Bill Layher, Kansas Department of Wildlife & Parks, Pratt, KS 67124). Standard procedures for evaluating habitat have been suggested as a means for determining the effects of impacts on wildlife, the differences in habitat use by wildlife, as well as, developing mitigation recommendations on a more objective basis (Anderson and Shugart 1974; Asherin et al. 1979; Capel and Lutey 1979; James and Shugart 1970; Rappaport 1979; Short and Schamberger 1979).

The foundations of habitat models, which can be used in these evaluation procedures to interpret habitat variable measurements, are species-habitat relationships. Habitat is defined as an area where most or all life requisites (food, cover, water, nesting substrate, etc.) of a species are found (Anderson 1980). Species specific traits enable birds to select habitat based on habitat dependant factors (Balda 1975). These factors, termed proximate factors (Hilden 1965), serve as an indication of habitat suitability and probable success of the species.

The U.S. Fish and Wildlife Service has developed Habitat Suitability Index (HSI) models for many vertebrate species, as part of its Habitat Evaluation Procedures program. Specifically, an HSI model identifies important habitat variables assumed to limit the success or occurrence of a species in an area. This allows comparison of the existing condition of that variable to a hypothetical optimum. Each variable is then quantified through the use of habitat measurement techniques. In most of the models, each variable is assigned a numeric suitability index (SI) value. This value can range from zero to 1.0, with 1.0 representing an optimal condition and zero representing totally unsuitable habitat. The SI values are based on the existing database for that variable and species. The assigned SI values are aggregated by one of several techniques to derive an overall HSI for the study site. The

HSI is assumed to be a linear index of the carrying capacity of a site (U.S. Fish and Wildlife Service 1981). Thus, as the HSI for a given species increases, the numbers of that species the area should be able to support, should increase, as well. Multiplication of the HSI value by the area of available habitat gives the number of habitat units (HUs) available at each site. Habitat units incorporate both habitat quality and quantity in one numeric index and can be used to make habitat comparisons between study sites or between pre- and post-construction conditions at a single site.

The black-capped chickadee (Parus atricapillus) and downy woodpecker (Picoides pubescens) were selected as study species because they are common and widespread residents of riparian communities in eastern Kansas (Johnston 1964). They are also members of the cavity-nesting guild (Bent 1939; 1946). Of those birds found in riparian habitats, a large percentage are dependant upon snags or dead portions of trees. Approximately 85 species of North American birds excavate nesting-holes, use natural cavities caused by decay, or use holes created by other species in dead or deteriorating trees (Scott et al. 1977). Approximately 30 percent of the breeding species in western forests are cavity-nesting birds (Raphael 1981). Evans and Conner (1979) stated that hole-nesting species comprise at least 20 percent of the bird species in the northeastern U.S.

Thirty-five cavity-nesting species are found in the Great Plains primarily in riparian habitat areas (Tubbs 1980). Brawn (1979) found that 48 and 37 percent of the breeding pairs belonged to the cavity-nesting guild on two study areas in Missouri. Members of this guild tend to have a low tolerance for habitat alterations because of their specific reproductive requirement (Brawn 1979, Stauffer and Best 1980, Tubbs 1980). Snags sometimes become limiting for those species dependant on them because forest managers often deem them undesirable and uneconomical.

The objectives of this study were 1.) to test the HSI models developed by Schroeder (1983a,b) for the black-capped chickadee and downy woodpecker; and 2.) to determine the ability of these models to predict changes in habitat likely to be associated with stream channelization projects in riparian areas of eastern Kansas. Effects of the stream channelization on the populations of these species. Habitat indices were compared with estimates of bird density to determine relationships between these species and the structure of habitats found in this area.

MATERIALS AND METHODS

Twenty-five bridge construction sites were selected in the eastern 1/3 of Kansas during the summer of 1988 (Figure 1, Table 1). The length of the habitat disturbance at the construction sites ranged from zero (a proposed project) to 260 m, with at least one streambank being altered at each site. Other than the proposed project, each site had some form of stream channelization associated with the construction. Dates of construction ranged from one site which was under construction at the time of sampling, to 1983. A corresponding control site approximately 1.6 km (1 mile) from the impacted area was sampled along the same drainage in which each construction site was located. Control sites represented the suitability of native riparian habitat as it would have been if the alteration had not occurred. In order to allow comparisons between habitat measurements at control and impact sites, a definite area had to be delineated. An arbitrary rectangle 300 m wide and 150 m long was established at all sites, with the creek channel running lengthwise through the center. This area was chosen because it was large enough to allow adequate sampling of the habitat variables in several cover types and small enough to allow detection of the effects of the disturbance, if any. Habitat and bird data for both impact and control sites were collected to represent this 4.5 ha plot at each study site (Figure 2).

Figure 1. Locations of study sites. Circles represent one pair; an impact and its control. For exact locations, see Table 1.

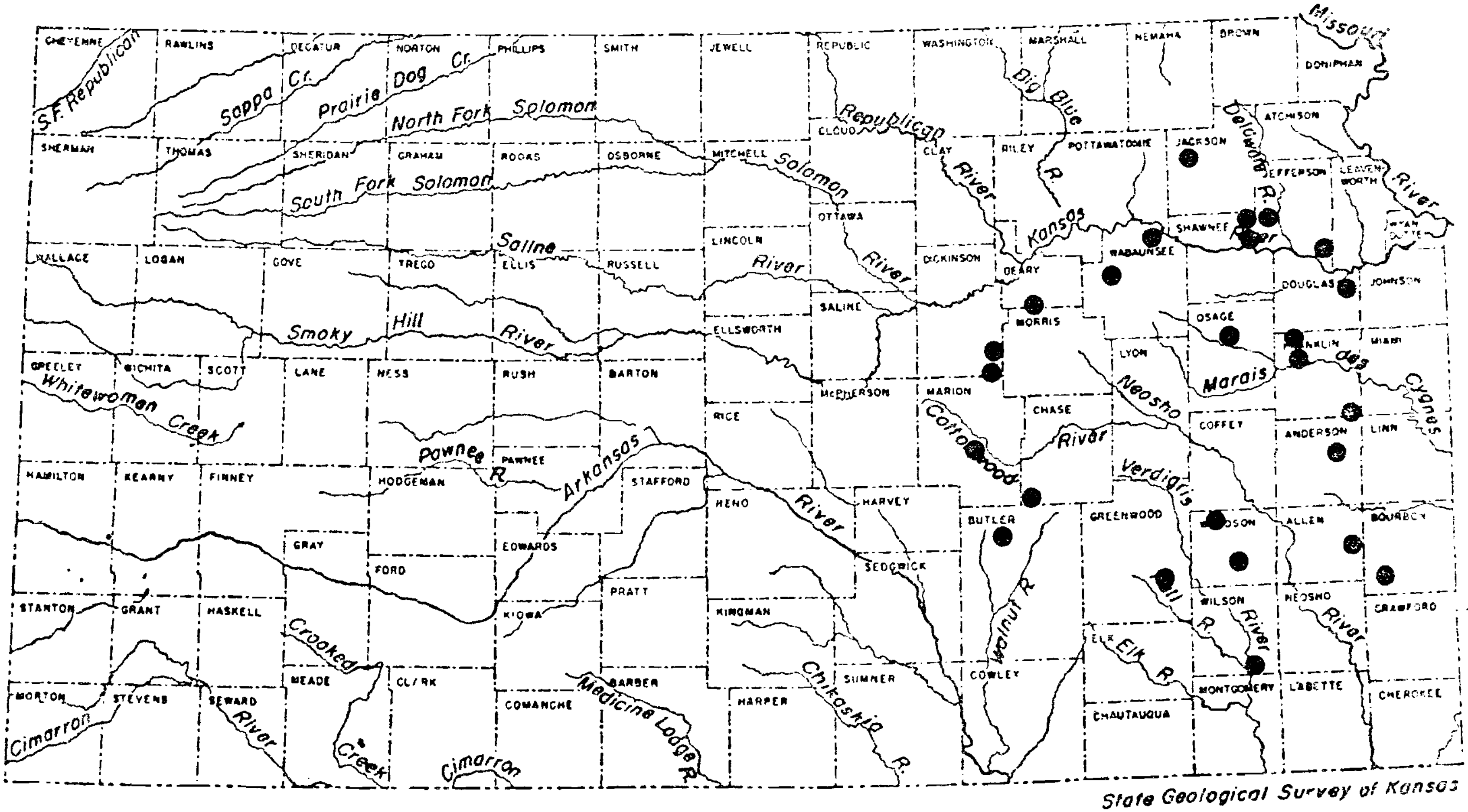
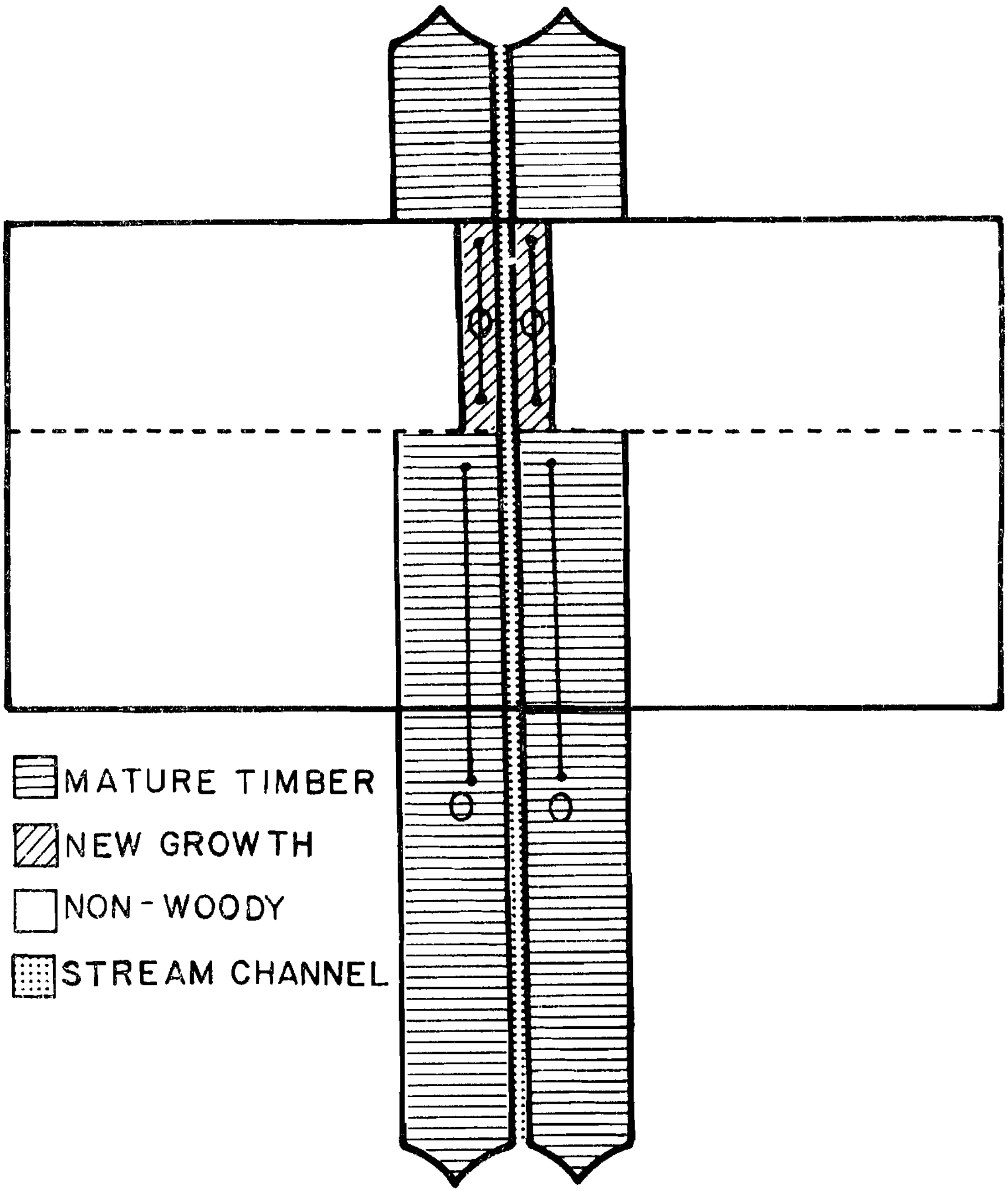

State Geological Survey of Kansas

Table 1. List of study sites, locations, and legal descriptions.

County	Stream name	Site	Legal description
Allen	Marmaton River	AL1115C AL1115T	NW1/4, S16, T25S, R21E SW1/4, S32, T24S, R21E
Anderson	S. Fork Pottawatomie Creek	AN1118C AN1118T	NW1/4, S23, T20S, R20E S1/2, S11, T20S, R20E
Bourbon	Paint Creek	BB1614C BB1614T	SW1/4, S13, T26S, R22E NW1/4, S36, T26S, R22E
Butler	Diamond Creek	BU1715C BU1715T	NE1/4, S2, T24S, R4E SE1/4, S3, T24S, R4E
Chase	Cedar Creek	CS2612C CS2612T	SE1/4, S9, T22S, R6E SW1/4, S9, T22S, R6E
Dickinson	Cary Creek	DK1136C DK1136T	SW1/4, S20, T14S, R4E SW1/4, S10, T14S, R4E
Dickinson	W. Branch Lyon Creek	DK1138C DK1138T	SW1/4, S18, T15S, R4E SW1/4, S30, T15S, R4E
Douglas	Little Wakarusa Creek	DG1166C DG1166T	NW1/4, S18, T13S, R21E SE1/4, S18, T13S, R21E
Franklin	Eight Mile Creek	FR0845C FR0845T	SE1/4, S31, T15S, R19E SE1/4, S5, T16S, R19E
Franklin	S. Fork Sac Branch	FR1758C FR1758T	NW1/4, S6, T19S, R21E SW1/4, S1, T19S, R20E
Franklin	Eight Mile Creek	FR1951C FR1951T	SW1/4, S30, T15S, R19E NE1/4, S24, T15S, R18E
Geary	Thomas Creek	GE1564C GE1564T	SW1/4, S35, T13S, R6E NE1/4, S26, T13S, R6E
Greenwood	Bachelor Creek	GW1650C GW1650T	SW1/4,NE1/4, S30, T25S, R11E NW1/4, S28, T25S, R11E
Jackson	Soldier Creek	JA0400C JA0400T	SE1/4, S34, T6S, R13E NE1/4, S28, T6S, R13E
Jefferson	Rock Creek	JF0888C JF0888T	NW1/4, S36, T9S, R16E NE1/4, S7, T10S, R17E
Jefferson	Mud Creek	JF1664C JF1664T	SE1/4, S36, T11S, R19E SW1/4,NE1/4, S25, T11S, R19E
Marion	Spring Branch Creek	MN1510C MN1510T	NW1/4, S7, T20S, R4E SW1/4, S17, T20S, R4E
Osage	Hundred and Ten Mile Creek	OS0620C OS0620T	SW1/4, S27, T14S, R15E NE1/4, S2, T15S, R15E
Shawnee	Muddy Creek	SN0680C SN0680T	SE1/4, S14, T10S, R16E SE1/4, S10, T10S, R16E
Shawnee	Little Muddy Creek	SN1099C SN1099T	SE1/4, S2, T11S, R16E NW1/4, S2, T11S, R16E
Wabaunsee	Hendricks Creek	WB0919C WB0919T	SE1/4, S4, T12S, R10E SE1/4, S3, T12S, R10E
Wabaunsee	Roberts Creek	WB1583C WB1583T	SW1/4, S27, T10S, R11E SW1/4, S22, T10S, R11E
Wilson	Dry Creek	WL1840C WL1840T	SE1/4, S27, T30S, R16E NW1/4, S34, T30S, R16E
Woodson	South Owl Creek	WO0884C WO0884T	NE1/4, S25, T25S, R15E SW1/4, S32, T25S, R16E
Woodson	Duck Creek	WO1581C WO1581T	NE1/4, S27, T23S, R14E SE1/4, S23, T23S, R14E

Figure 2. Hypothetical impact site (rectangular area, 4.5 ha) containing three distinct cover types. Horizontal dashed line indicates the extent of impact. Diagonal striped areas represent new growth after impact; horizontal striped areas represent undisturbed riparian timber; and unmarked areas indicate unsuitable or non-woody vegetation. The stippled area represents the stream channel. Vertical lines within cover types are transects where habitat measurements were taken and open circles represent bird census points. Map scale: 1 cm = 21.4 m.



MATURE TIMBER
NEW GROWTH
NON-WOODY
STREAM CHANNEL

Bird Censusing Procedure

Censuses to estimate species response to habitat alterations were conducted at each site between 1 June and 11 July, 1988 using the variable circular-plot method described by Reynolds et al. (1980). This method was used because more time would be spent looking for birds from a stationary position with secretive birds being detected. Birds tend to be more active in the morning hours, shortly after sunrise during the breeding season (Shields 1977). Because of the gradual decline in activity as the day progresses, censuses were conducted between 0630 and 1100 CST. Impact-control site pairs were sampled concurrently by two observers; one at each site. Four censuses were completed at each impact site; two were located across the stream from each other within the actual impacted area where new growth occurred after construction, and two were located in the same manner approximately 150 meters away in the remaining mature riparian timber (Figure 2). This arrangement accounted for the "edge" effect as described by Gysel and Lyon (1980) and allowed comparisons to be made between an impact site and its control. The creation of edge or new vegetative forms tend to increase the numbers of some species of birds. Control site censuses were carried out as described above, except all were taken within the mature riparian cover types found at those sites. At each census point, the observer waited one minute before beginning the census. All birds observed or heard while approaching the census point were noted. Following this equilibrium period, the observer identified each bird seen or heard within a ten-minute time period and estimated the distance to the bird. Although care was taken to count an individual only once within a census period, an individual could have been counted at more than one census point within each site.

Distances from the observer to the bird were divided into five-meter bands for the black-capped chickadee and downy woodpecker. Records for both species were totaled by concentric bands for all control sites, all censuses taken within the impacted area of impact sites, and all censuses taken beyond the impacted area because of the similarity of cover types within these three groups. Data were so grouped because of the differences in detectability of birds between these groups. These totals were then divided by the number of censuses in each group (n = 100 for controls; n = 50 each for impacted parts of impact sites and observations beyond the impacted area), yielding a mean number of birds sighted for each band. After computing the area of each five-meter band, a mean density of birds for each band per group was obtained. By determining the distance to the outermost edge of the band with a density of at least two times that of the next, or any, outermost band, the effective detection distance for each group was obtained (Reynolds et al. 1980).

Density for each individual site was calculated by counting the actual number of individuals for each species seen within a circle with a radius equal to the effective detection distance.

Habitat Sampling Procedure

Habitat measurement techniques described by Hays et al. (1981) were applied to each cover type within the immediate area to estimate values for model variables. When data were collected from only the impacted part of impact sites (n = 13 impact sites, appendix A and B), habitat characteristics in the undisturbed portions of the impact sites were assumed to be equal to that of the corresponding control site. Habitat sampling was conducted between 31 May and 30 September, 1988. Cover types were determined from visual inspection of the area. Differences in the vegetative life form, or physiognomy, separated one cover type from another.

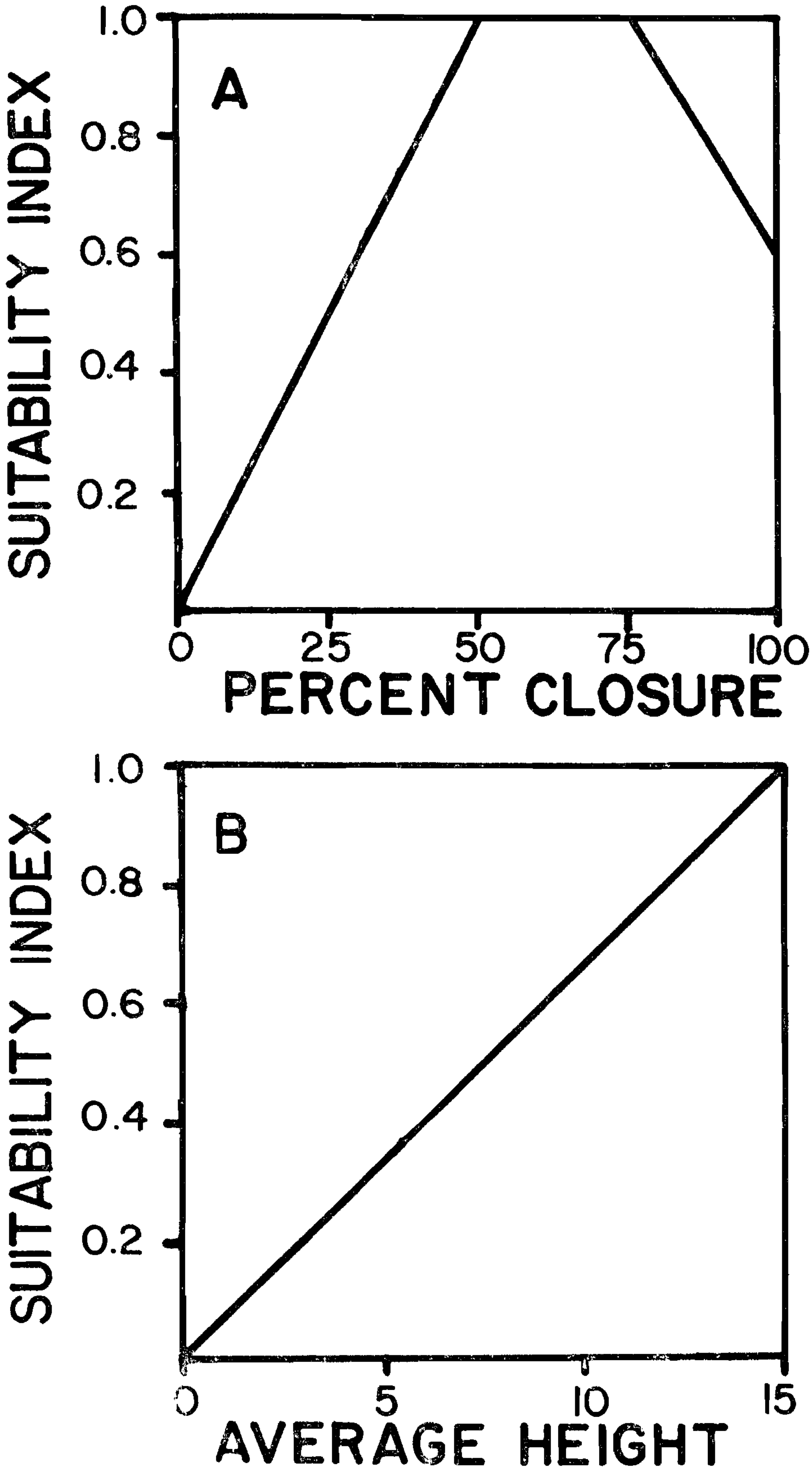
Black-capped Chickadee

Percent tree canopy closure and the average height of overstory trees are the variables for the food component of the black-capped chickadee model. A combination of these variables is assumed to reflect canopy volume. Canopy volume of trees appears to be the proximate cue used by black-capped chickadees in Washington to determine potential food supply because their abundance showed a strong positive correlation with canopy volume (Sturman 1968a). It is assumed that chickadee abundance is related to insect abundance, and insect abundance is correlated to canopy volume (Schroeder 1983a). Black-capped chickadees tend to forage in the lower zones, or subcanopy, of trees (Sturman 1968b). As canopy closure increases, it is assumed the lower subcanopy will be shaded out, resulting in suboptimal foraging habitat (see Figure 3a). Percent tree canopy closure is described as the percent of ground surface shaded by a vertical projection of the canopies of all woody vegetation taller than 5.0 m (Schroeder 1983a). Percent canopy was estimated by laying a line transect in each cover type and measuring the widths of the canopies which intercepted the line (Figure 2). By summing these widths and dividing by the length of the transect, percent canopy closure was obtained (Hays et al. 1981). Transect lengths varied, depending on the length of the cover type and the extent of impact. Canopy estimates were also measured using a spherical densiometer (see Lemmon 1957) with all but four of the mirrored quadrants covered. Estimates were measured by reporting the percent of the quadrants which was covered by overstory foliage. Measurements were taken at every 20-meter mark (Figure 2). This technique was added for its ease in use and for comparisons with the method described above.

The average height is used because as the height of the stand increases, it is assumed foraging substrate will increase, as well (Figure 3b). The average height of the

Figure 3. A: Suitability Index for percent tree canopy closure of the black-capped chickadee model. Optimum suitability is achieved at closures between 50 and 75 percent.

B: Suitability Index for average height of the overstory of the black-capped chickadee model. Areas averaging at least 15 meters in height receive an SI of 1.0. The SI for the food component is the geometric mean of the SI values for these two variables (both after Schroeder 1983a).



A
SUITABILITY INDEX
1.0
0.8
0.6
0.4
0.2
0
25
50
75
100
PERCENT CLOSURE
B
SUITABILITY INDEX
1.0
0.8
0.6
0.4
0.2
0
5
10
15
AVERAGE HEIGHT

overstory is defined as the average height from the ground surface to the top of those trees which are >= 80% of the height of the tallest tree in the stand. Heights were measured for every tree intercepting a transect line using a telescoping pole for shorter trees and a clinometer for taller trees (Hays et al. 1981). These variables were used because they are easier to measure than actual canopy volume (see Sturman 1868a), but their application to predict canopy volume has not been well tested (Schroeder 1983a). To obtain an SI value for the food component of the chickadee model, the geometric mean of the SI values for the two variables is used.

The black-capped chickadee is a secondary cavity-nester and the reproduction component of the model was estimated by counting the number of snags within a 10 m wide belt transect. A snag is described as a standing dead or partly dead tree which is least 1.8 m tall (Schroeder 1983b). Trees in which at least 50% of the branches have fallen, or are present but no longer bear foliage were considered as snags. Black-capped chickadees nest primarily in small dead or hollow trees. Snags having some heartrot but firm sapwood are usually chosen (Brewer 1961), because the chickadee is a weak excavator. Chickadees will also nest in old cavities made by primary cavity-nesters. Preferred snags range from 10 to 15 cm diameter at breast height (dbh) (Brewer 1963). Suitable snags for the model are those which meet the requirements above and are within a 10 - 25 cm dbh range (Schroeder 1983a). Sites containing five or more 10 to 25 cm dbh snags/ha are considered to be optimum for the reproduction component (see Figure 4). The overall HSI for the chickadee is the minimum SI of the two requisite components.

Downy Woodpecker

Downy woodpecker model variables are: 1.) basal area (m^2/ha), and 2.) the number of snags greater than 15 cm dbh per ha (2.47 acres). Basal area represents the food component of the model. Downy woodpeckers are bark foragers and forage more in the lower height zones of live trees (Williams 1975). Downy woodpeckers in Kansas forage in relatively small trees at a certain position or site relative to the height of the tree, with females selecting taller trees than males (Jackson 1970). Basal area is a measure of stand maturity and structure (Hovind and Rieck 1970, Gysel and Lyon 1980), and it is assumed that sites with high basal areas will contain less optimum foraging substrate for downy woodpeckers (Figure 5a), because of the potential shading out of the smaller trees used for foraging. Downy woodpeckers foraged most often in the breeding season in habitats with significantly lower basal areas (Conner 1980). Basal area is the area of exposed stems of woody vegetation if cut horizontally at a 1.4 m (4.5 ft) height (Hays et al. 1981). This variable was

Figure 4. Suitability Index for the reproduction component of the black-capped chickadee model. Sites having at least five snags/ha receive an SI of 1.0 (after Schroeder 1983a).

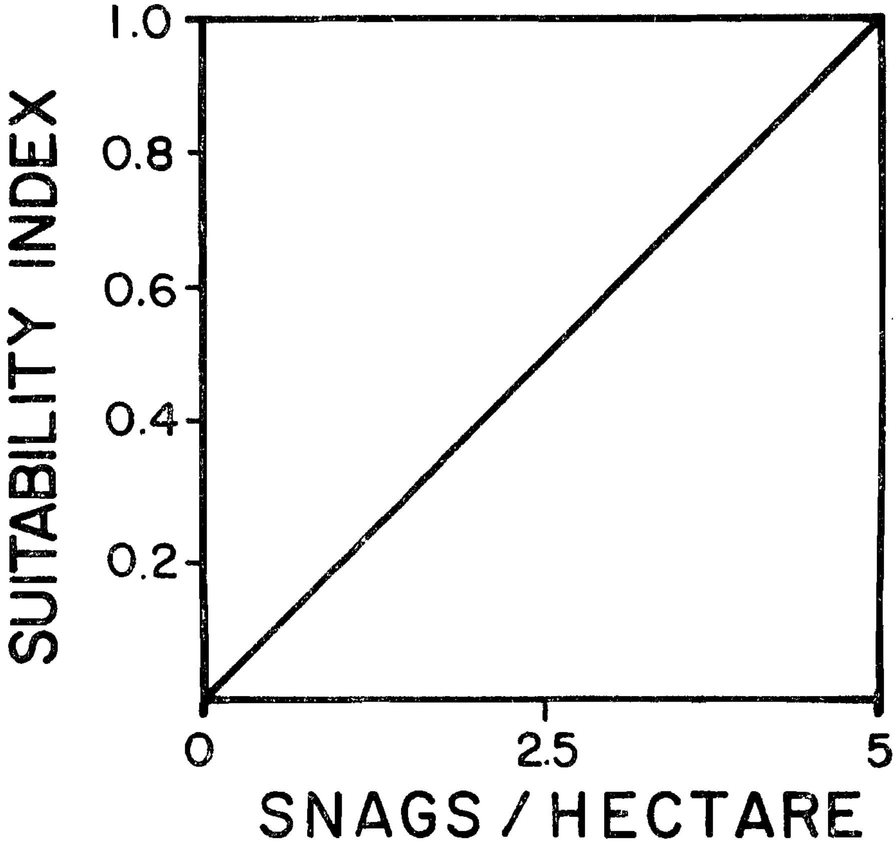
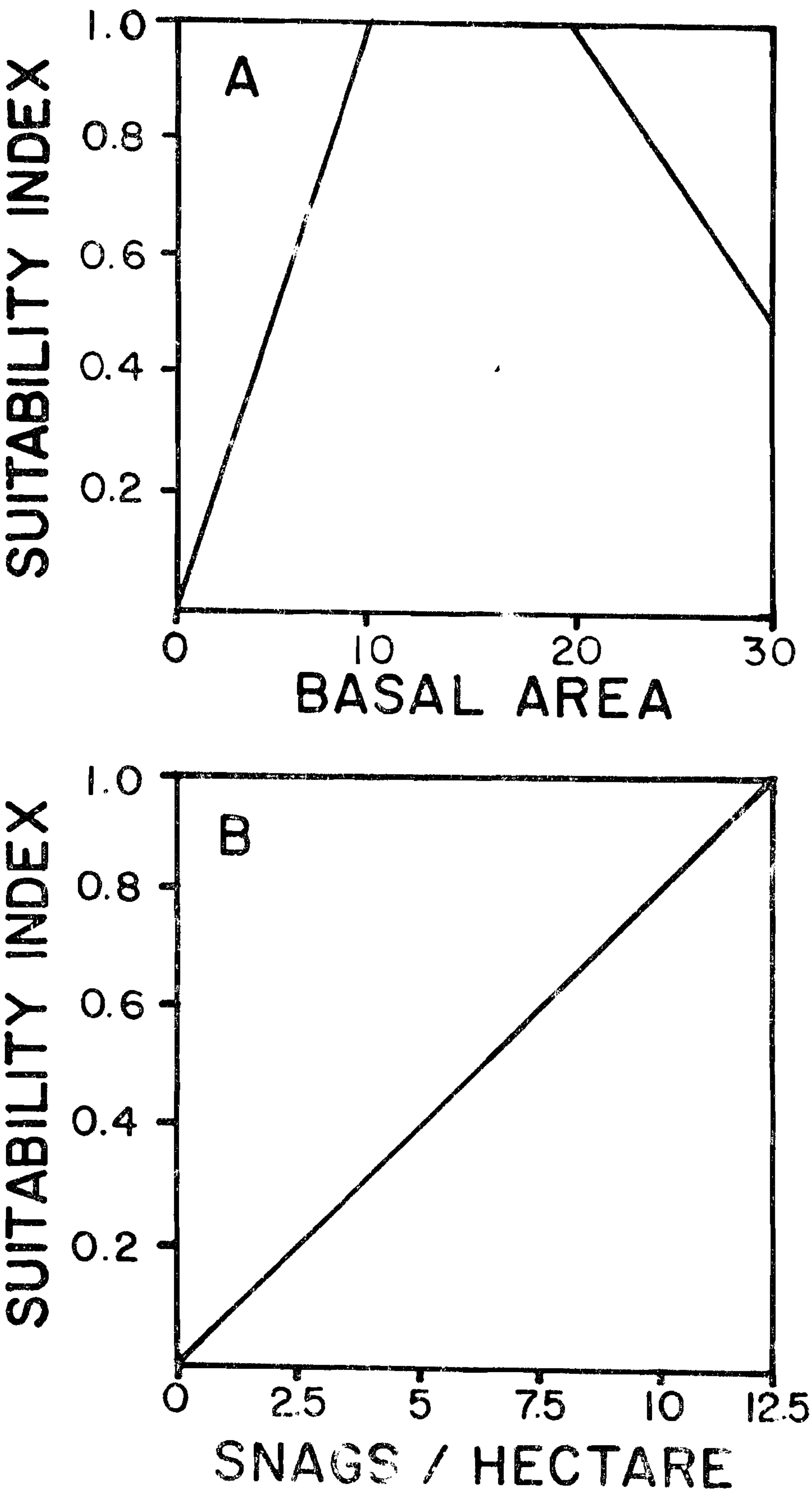

1.0
0.8
0.6
0.4
0.2
SUITABILITY INDEX
0
2.5
5
SNAGS / HECTARE

Figure 5. A: Suitability Index for the food component of the downy woodpecker model. Sites having basal areas between 10 and 20 m^2/ha receive an SI of 1.0.

B: Suitability Index for the reproduction component of the downy woodpecker model. Sites having at least 12.5 snags/ha receive an SI of 1.0 (both after Schroeder 1983b).


A
B
SUITABILITY INDEX
1.0
0.8
0.6
0.4
0.2
0
10
20
30
BASAL AREA
SUITABILITY INDEX
1.0
0.8
0.6
0.4
0.2
0
2.5
5
7.5
10
12.5
SNAGS / HECTARE

estimated using an angle-gauge having a basal area factor (BAF) of 1.15 m^2/ha (5.0 ft^2/acre). A transect was laid out in each cover type with basal area measurements taken at each 20-meter mark (Figure 2). The angle-gauge was rotated 360 degrees about the observation point; each live tree larger than the BAF opening was counted as a "hit". If a tree was questionable in being "in" or "out", it was counted as one half (Hays et al. 1981).

The reproduction component of the downy model is measured by estimating the number of snags > 15 cm dbh per ha. The downy woodpecker is a primary cavity-nester preferring soft snags for nest sites (Evans and Conner 1979). Suitable snags are those which facilitate excavation by having some form of heart rot (Conner et al. 1976). Both sexes usually help in excavating the cavity (Kilham 1962), which usually occurs in snags greater than 15 cm dbh. Sites containing more than 12 snags/ha are considered optimal (see Figure 5b) because of the need for extra snags for the nonincubating parent, and roosting sites for fledged young before dispersal (Short 1979). In the present study, a belt transect was used in each cover type to estimate the number of snags (Figure 2). Each suitable snag within a 10 m wide belt was counted for each cover type. The overall HSI of a site is determined as the minimum SI of the two life requisite components.

RESULTS AND DISCUSSION

Black-capped Chickadee

A total of 2,349 individual observations of birds was recorded for 200 ten-minute census periods, representing 68 species and 5 unknown categories. The cavity-nesting guild was represented by sixteen species, accounting for about 24 percent of the known species total. Three hundred and thirty birds were identified as black-capped chickadees, making up 14 percent of the total individual observations recorded and nearly 41 percent of the cavity-nesting guild. Black-capped chickadees were sighted at all but three sites (one control and two impact sites), with an estimated mean density of 2.7 birds/ha (Table 2). See appendix A for the chickadee densities and habitat data for each site.

Table 2. Density and HSI estimates for the black-capped chickadee and downy woodpecker.

	Density (birds/ha)		HSI	
	Range(n)	Mean(SD)	Range(n)	Mean(SD)
Black-capped chickadee[a]	0.0 (3) - 7.96 (1)	2.7 (1.8)	0.0 (7) - 1.0 (2)	0.57 (0.37)
Downy woodpecker[b]	0.65 (14) - 4.55 (1)	1.4 (1.1)	0.0 (4) - 1.0 (5)	0.61 (0.38)

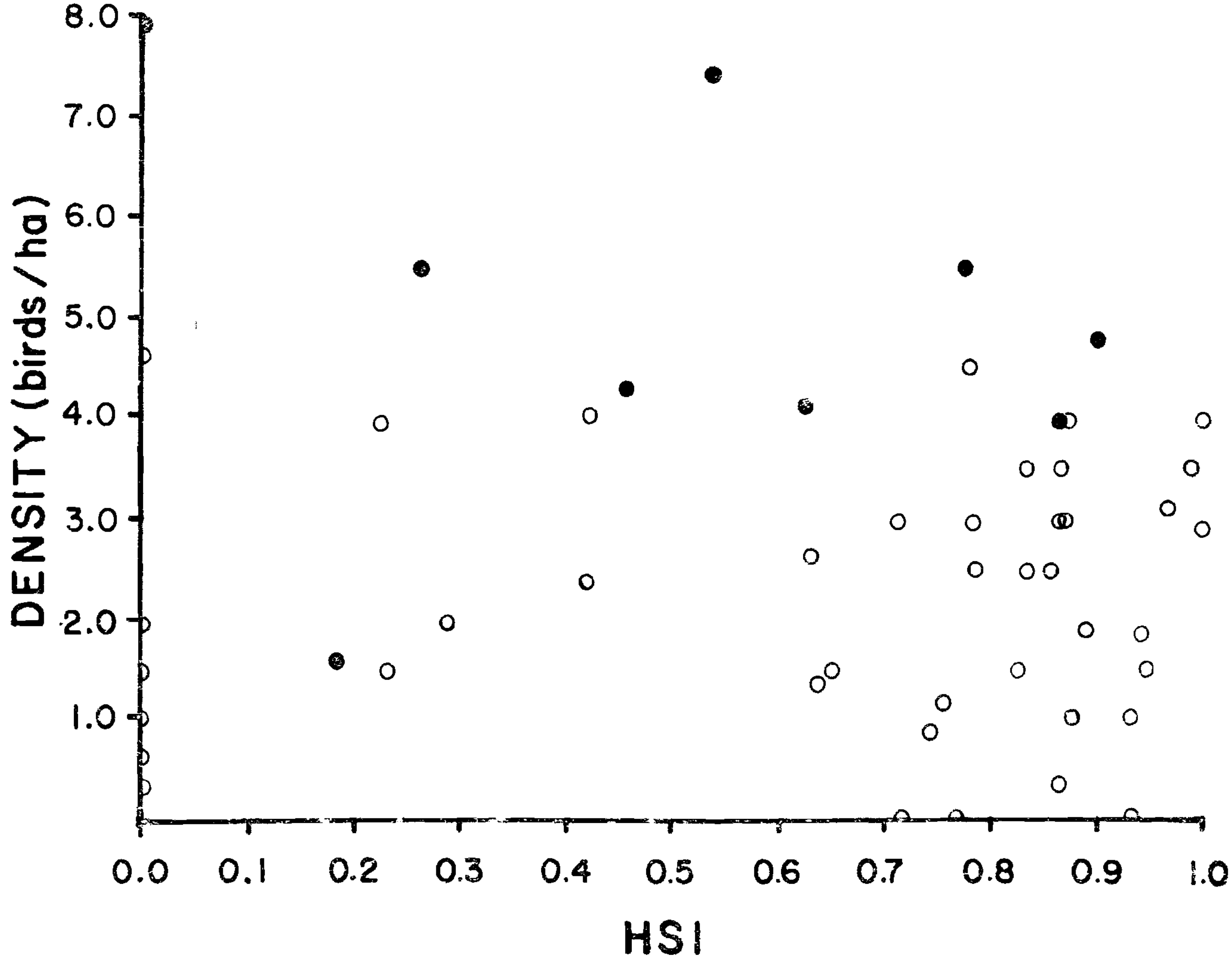
[a] - n = 50 sites.
[b] - n = 25 sites. Ranges of densities and HSI values are from those sites where the downy woodpecker was sighted within a 35-meter detection distance.

In the attempt to test habitat models, one compares units of model output with some estimate of species response. If the species-habitat relationships outlined in the model are sufficient to define the species response, the data should follow a diagonal line with a slope of one. Departures from this line represent either high HSI-low use or low HSI-high use areas, and subsequent failure of the model. Deviations caused by the latter appear to be more critical; cases of the former may not be relevant to timely management decisions because the assumption of carrying capacity hasn't been met (Lancia and Adams 1985) due to factors other than habitat affecting density levels.

Density vs HSI

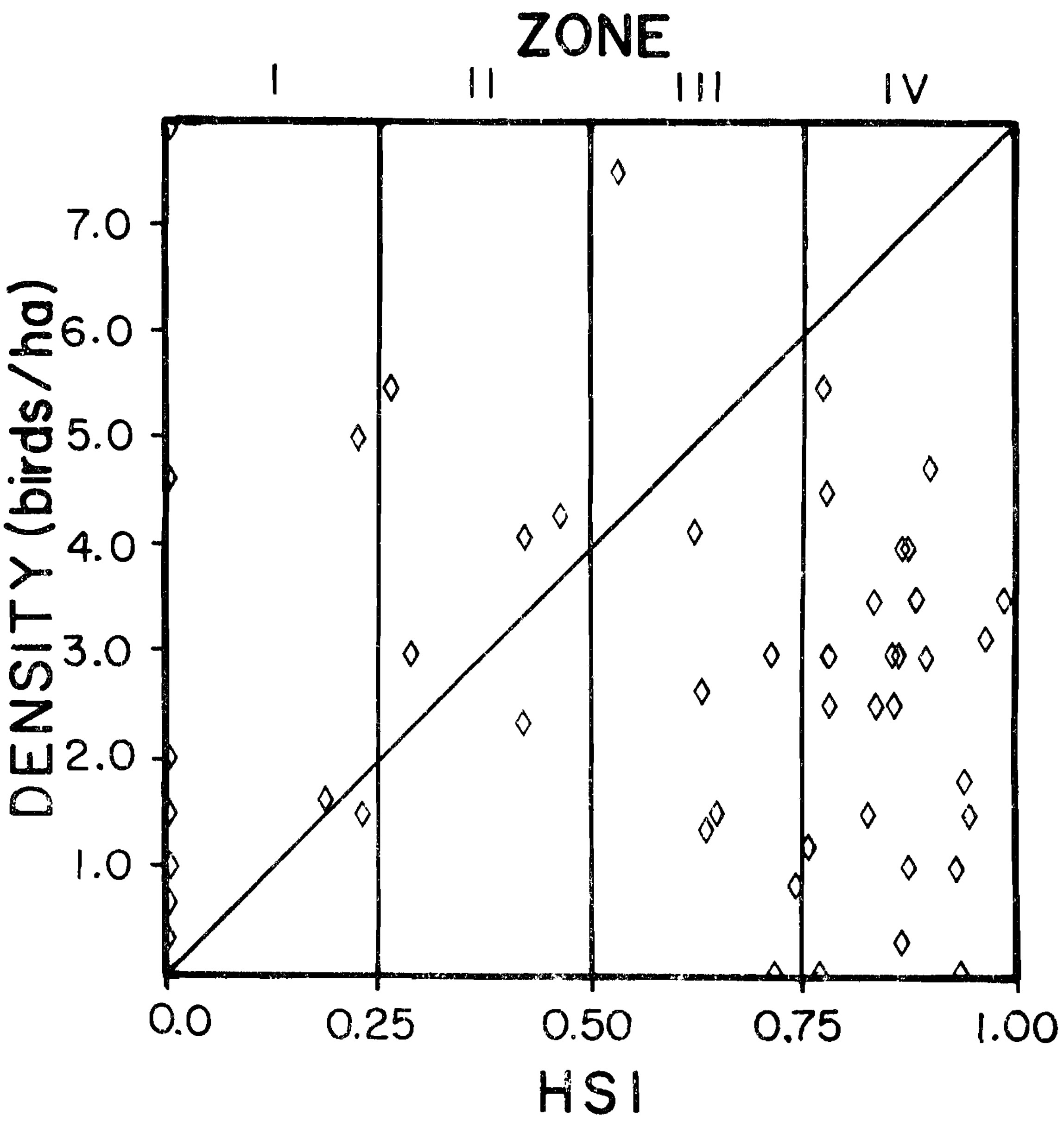
There was no relationship between chickadee densities and HSI values ($r = -0.01$) for all 50 sites (Figure 6). By removing the 13 impact sites where assumptions concerning the habitat at control sites were used, there was still no relationship between density and HSI ($r = 0.00$). A chi-square analysis was performed to evaluate the model's abilities in defining the upper limits of species response. A graph having equal axes lengths was constructed with the highest observed density being the maximum y-axis value. Thus, density (0 to 7.96 birds/ha) and HSI (0 to 1.0) yield an equal-axis graph with the assumed relationship being a 45° line passing through the origin (Figure 7). Only HSI values < 1.0 were plotted because species response cannot

Figure 6. Relationship between black-capped chickadee densities (birds/ha) and HSI ($r = -0.01$, $P > 0.5$). Dark circles are the maximum density estimates used to evaluate the model's ability to predict the upper limits of species response.



8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
DENSITY (birds/ha)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
HSI

Figure 7. Black-capped chickadee densities plotted against HSI in an equal-axis graph used in conjunction with a chi-square analysis to test whether the data are habitat limited or uniformly distributed. Zones I-IV contain 87.5, 62.5, 37.5, and 12.5% of the area above the line, respectively.


ZONE
I
II
III
IV
DENSITY (birds/ha)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.25
0.50
0.75
1.00
HSI

occur above the line when HSI = 1.0 (U.S. Fish and Wildlife Service 1987). The graph was divided into four zones and observations were tabulated both above the line, where performance exceeds the assumed habitat limitations, and below the line, where observations can occur and not invalidate the model. Incorrect HSI values occurring above the line are compared with those below it by multiplying the total number of observations in each zone by the area above and below the line to give the number of expected observations. In this way, one can determine whether the observed data are habitat limited as opposed to being uniformly distributed. This method assumes habitat is sufficient to define the upper limit but not the exact level, of species performance (U.S. Fish and Wildlife Service 1987). Overall performance of the HSI model in predicting upper limits of black-capped chickadee response was poor (Table 3).

Additional analysis was performed by dividing the HSI values into ten quality classes and plotting the maximum species density for each class. If HSI properly measures habitat quality, the maximum species response in habitats with low HSI values should be lower than in habitats with high HSI values (U.S. Fish and Wildl. Serv. 1989) Again, the assumed relationship should yield a 45° line passing through the origin. Testing the HSI-density output in this manner yielded no relationship (Figure 6, Table 3).

Table 3. Chi-square and regression analyses of the upper limits of the density-model output relationships for the black-capped chickadee.

	Chi-square[a]				Regression[b]
Zone	I	II	III	IV	r
HSI	.80	.59	.12	.01	-0.015 (P > 0.5)
Snag SI	.57	.59	.89	.08	-0.127 (P > 0.5)
Canopy SI	---*	.04	.01	.14	0.784 (P < 0.1)
Height SI	---	.04	.17	.02	0.675 (P < 0.1)
Food SI	---	.04	.01	.14	0.928 (P < 0.005)

[a] - G-statistic values
[b] - Regression of maximum density values for ten habitat quality classes. These statistics correspond to the dark circles found in figures 6, 8a, 8b, 9a, and 9b.
* - No observations in this zone.

This could be the result of one or more of three occurrences: 1.) the bird sampling techniques were not adequate and estimates of abundance were inaccurate; 2.) the habitat sampling techniques or design did not adequately estimate the quality of habitat available; or 3.) the model doesn't predict chickadee abundance at the sites which were studied. The lack of relationship between HSI and density is the result of the inability to estimate snag densities accurately.

Because chickadees were sighted at all but three sites, the censusing efforts seem to be adequate. Chickadee territories tend to decline during the incubation and nestling stages (Stefanski 1967), and subdominant individuals, which nest later, will nest in the "spaces" created by the absence of defense by aggressive chickadees (Glase 1973). This behavior allowed ample detection of the chickadee. Assuming equal proportions of the sexes, the mean density found in this study (2.7 birds/ha) is almost equal to the mean of 1.4 males/ha from the top five Breeding Bird Census reports from recent studies (Schroeder, U.S. Fish & Wildlife Service, unpublished). The sampling design assumed there was an equal chance of an individual being sighted at each observation point, and should have provided an adequate estimate of abundance between sites.

Sampling methods for percent canopy cover and average overstory height were adequate. One-hundred meter transects were divided in half to compare the variable estimates. When the halves of the control cover types were compared to the original 100 m transect using a two-sample t-test, there was no difference ($P = 0.87$) and there seemed to be a correlation ($r^2 = 0.78$). Because of the way average height was obtained, there were differences between 100 m and 50 m transects in mature riparian cover types ($P = 0.0$). However, in most cases, only a handful of trees were used in the calculation of this variable. Often only one because of a very tall tree found in the stand and none that were at least 80% of its height. When all trees greater than 5 m were considered for this variable (see discussion below), there were no differences ($P > 0.5$).

However, the sampling design should have included more area for estimating the densities of snags because only high and low snag densities dominated the data (appendix A, Table

5). In estimating snag densities, a snag found within a 10 X 100 m belt (0.1 ha) would yield a density of 10 snags/ha and an SI of 1.0, while finding zero snags yielded an estimate of zero snags/ha and an SI of 0.0. Sixty-five percent of the mature riparian cover types measured and 58% of the sites examined were estimated to have more than 15 snags/ha, which is far more than needed to be optimum habitat for chickadees (see Figure 5). Seven sites were estimated as having no snags. Sampling a larger area for snags would have given a better range of estimates.

In addition, a narrower definition of snags might better depict suitability for the reproduction component. A snag, as defined earlier, is any dead or partially dead tree with at least 50% or more of its branches or foliage missing. Because chickadees are weak excavators, they must rely on soft snags or unused cavities. The HSI model definition of snags does not give consideration to the degree of decomposition of snags or to the number of cavities suitable for chickadees. In Missouri, Brawn (1979) found the mean decay class of chickadee snags to be 4.2, with classes ranging from one to five in ascending degree of decomposition. Stauffer and Best (1980) in Iowa found that secondary cavity-nesters, in general, chose dead limbs of live trees more often than primary cavity-nesters but 92% of the chickadee nests were in snags of soft or intermediate conditions. Because woodpeckers often require snags with some degree of deterioration (Conner et al. 1976), one could assume chickadees would nest in older, more decomposed snags because of their inability to excavate and the lag time between woodpecker and chickadee inhabitance. Runde and Capen (1987) found 93% of the chickadee nests in Vermont to be in snags. Sedgwick and Knopf (1986) found a large percentage of cavities in live trees in Colorado cottonwood bottomlands. Although there were few snags, there were proportionately more cavities in snags compared to their availability. Schroeder (unpubl.), in a test of the model, suggested the combination of snag density and the density of trees having at least one suitable cavity as a measure of nest site availability. Another addition could be the decay class of snags. To be suitable, a snag would not only meet the diameter requirements but also be in some stage of advanced decay. These modifications might alleviate differences in the local or regional nesting preferences of chickadees and more accurately depict their nesting limitations.

Density vs SI

To better detail the lack of relationship between HSI and density, chickadee abundance was compared to SI values for each variable. Although the area of suitable habitat may have differed between sites, birds were censused only within the immediate riparian corridor, that is, censuses did not vary with the amount of timber present. Habitat units were not used in the comparisons of model output and density because of this design. The chi-square test was also performed with variable SI values. As can be seen from Table 3, results of the canopy, height, and food SI tests indicate these data are closer to being habitat limited than either the snag or HSI data. Probabilities are given in Table 3 without reference to statistical significance so that users can evaluate for themselves which is appropriate.

The range of weighted SI values of each variable was divided into ten classes and compared to the maximum species density of that class. For the chickadee model, there was little relationship between the availability of snags and chickadee densities (Figure 8a, Table 3). A better method of sampling snags might have given a better relationship between this variable and chickadee density.

Percent canopy cover was the best predictor of the upper limits of chickadee abundance (Figure 8b, Table 3). Mean chickadee densities were highest at sites having SI values of 0.6 or greater. Average height of the overstory was next (Figure 9a, Table 3), with the highest mean densities occurring at areas having SI values > 0.7. The food SI also correlated well with black-capped chickadee densities (Figure 9b, Table 3). This would suggest a relationship between canopy volume and chickadee densities. Sturman (1968a) proposed a technique to measure canopy volume by determining a trees' shape, either a coniferous or

Figure 8. A: Relationship between black-capped chickadee densities (birds/ha) and snag SI ($r = -0.01$, $P > 0.5$).

B: Relationship between black-capped chickadee densities (birds/ha) and canopy SI ($r = 0.03$, $P > 0.2$). Dark circles, in both graphs, represent maximum density estimates used to evaluate the SI's ability in predicting the upper limits of species response.

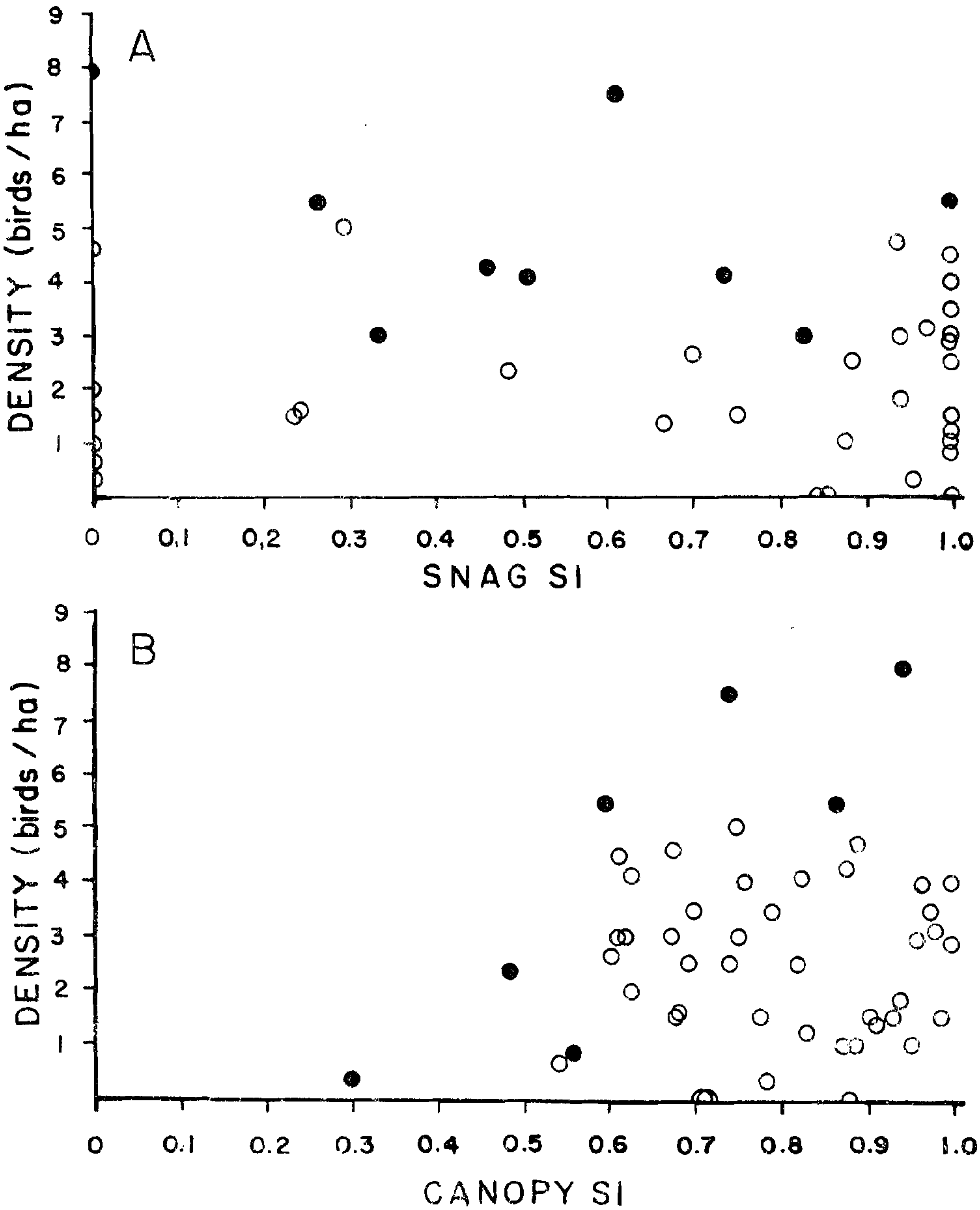
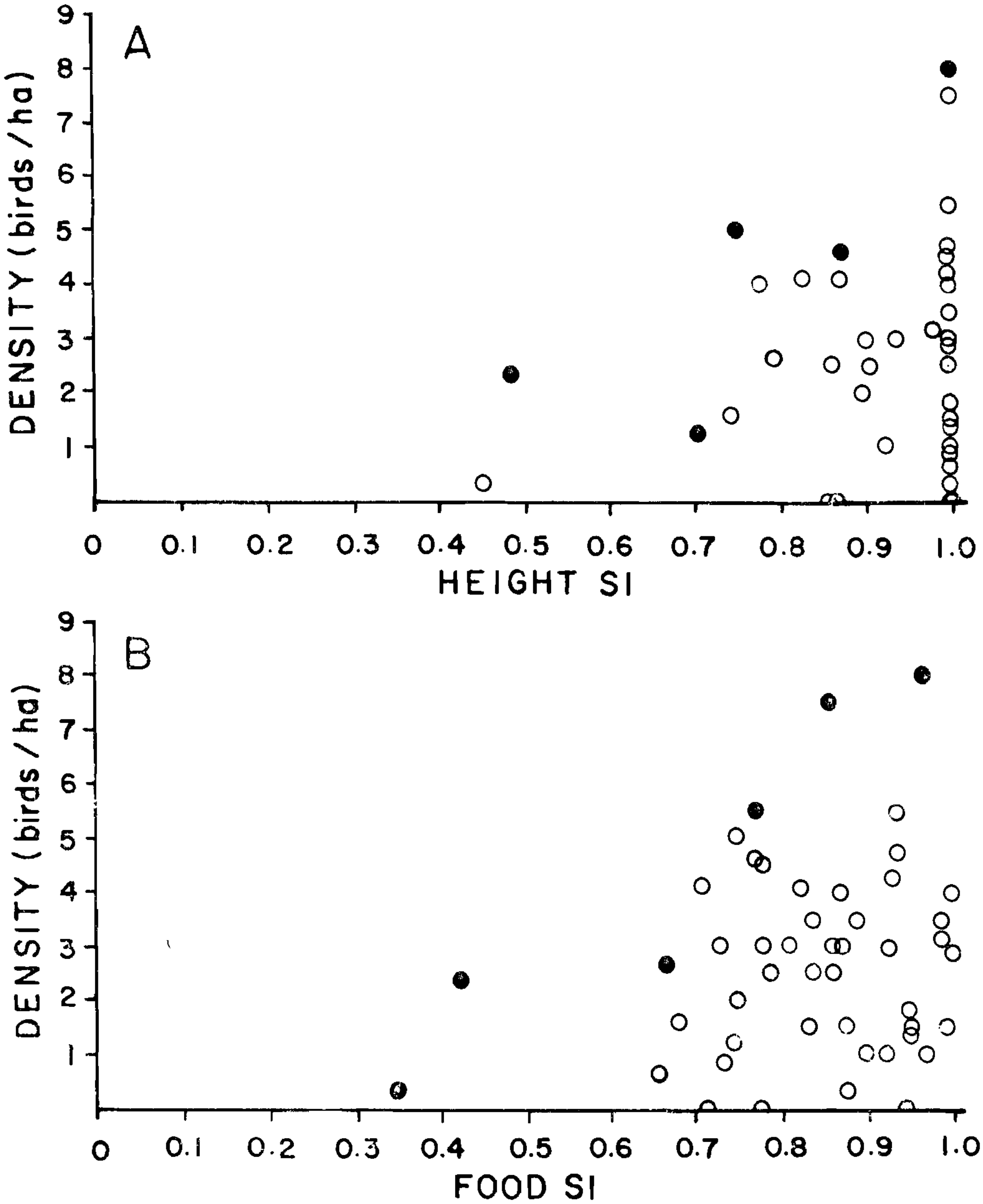

A
DENSITY (birds / ha)
SNAG SI
B
DENSITY (birds / ha)
CANOPY SI

Figure 9. A: Relationship between black-capped chickadee densities (birds/ha) and height SI ($r = 0.13$, $P > 0.5$).

B: Relationship between black-capped chickadee densities (birds/ha) and food SI ($r = 0.11$, $P > 0.2$). Food SI values are the geometric mean of canopy SI and average height SI values. Dark circles, in both graphs, represent maximum density estimates used to evaluate the SI's abilities in predicting the upper limits of species response.


A
DENSITY (birds / ha)
HEIGHT SI
B
DENSITY (birds / ha)
FOOD SI

deciduous one, and measuring both the inside and outside crown. Because of the time and difficulty involved in measuring canopy volume, an alternate model was used in which the average height of the overstory and percent tree canopy closure variables are assumed to reflect canopy volume (Schroeder 1983a). The HSI for the food component is obtained by taking the geometric mean of the SI values for average height and canopy cover. In a revision to the original model, Schroeder (unpubl.) gave maximum SI values for sites having >= 70% canopy cover and average heights over 25 m, with this variable including all trees >= 5 m. Average heights < 5 m would receive an SI of zero. In addition, the product of the SI values was used because volume is a function of the product of height and area. This revision more closely predicted canopy volume at his study sites. These revisions gave no relationship (r = 0.00) with density when used to compute HSI values in this study. Calculated HSI values were lower, with the highest HSI given during this revision being 0.58. Plotting the maximum densities of this study against the revised HSI classes gave a stronger relationship than the original (r = -0.55) but it was negative. Because of the influence of the snag data, food SI values from this revision for all quality classes were compared with density. This yielded a strong relationship, but lower than the original model (r = 0.83).

I also changed the model to see if any modifications would yield better relationships between density and food SI. I lowered the height requirement for high SI values of Schroeder's revision because the maximum average height, when using all trees > 5 m in this study, was approximately 16 m. By using the geometric mean of this variable and canopy cover, where canopies greater than 70% received SI values of 1.0, a weaker relationship was obtained ($r = 0.55$). I also used the geometric mean of the average height of all trees > 5 m and giving SI values of 1.0 for canopy between 50 and 70% ($r = 0.52$). The best revision used the original height requirement and gave high SI values for canopy >= 70%, and took the geometric mean of these values. This yielded a better relationship than the first revisions ($r = 0.84$), but it wasn't as strong as the original model (Table 3). The method of computing the average height and canopy cover SI values from the original model seems to better predict the upper limits of chickadee response in eastern Kansas.

Because of the strong relationship between chickadee densities and the food component of the original model, the assumptions concerning canopy volume appear to be valid. However, because of the weak correlation with snag densities and the discontinuous snag density estimates, the relationship between chickadee abundance and HSI values cannot be adequately tested.

Measurement Techniques

Several problems were apparent in using the variable measurement techniques suggested for the chickadee model. Percent canopy of the overstory was measured two ways: using a line transect as described by Hays et al. (1981) and a spherical densiometer. Some difficulties arose using both methods. Canopy cover, as described in the model, is the percent of ground surface shaded by the canopies of all woody vegetation taller than five meters. In the field, it became apparent the densiometer wasn't measuring what was described in the model. Because of the low shrub layer (< 5 m) present at most of the sites, percent canopy as estimated with the densiometer, represented more than the overstory. Anything higher than the densiometer and within range of the mirror was counted as overstory. At most impact sites, where the stream banks had previously been cleared for construction, the mean stand height did not exceed five meters.

In using the line transect, every woody plant intercepting the tape was recorded by measuring its height and its crown width intercepting the tape. By summing the crown widths of all trees >= 5 m, total overstory canopy would be obtained; dividing by the length of the transect would give percent canopy closure of the overstory. Because of the nature of most cover types and the amount of overlap among the canopies, percent canopy often exceeded 100. By developing a computer program which counted each point of the line covered as one, regardless of the amount of overlap, percent canopy cover of those trees greater than five meters was obtained. This technique should help other users of the model to avoid the problems encountered during this project.

Effects of Stream Channelization

Another objective of this study was to measure the effects of bridge replacement projects on the populations of riparian birds. Black-capped chickadee density estimates from control (non-channelized) sites were compared with those of impact sites, with the null hypothesis being densities would be equal between the groups. A two-sample t-test was used for comparison. Based on this analysis, there was a difference between the groups ($P = 0.06$) with control sites having higher densities. These findings correspond closely to those of Possardt and Dodge (1978), who found higher numbers of birds in non-channelized areas, with passerines being most affected, including black-capped chickadees. Although habitat units were not used in comparing a form of species response, they were used to compare the quality and quantity of habitat available between impact and control sites. There were also differences in this analysis ($P = 0.08$) with control sites having more habitat units. The proposed construction site (CS2612T, appendix A) was included with the control group for both analyses. As before, probabilities are given without mention of statistical significance, though it is apparent that changes did occur and differences do exist.

Most of the sites studied had a very narrow band of riparian timber, which is typical where agricultural and grazing operations are carried out within meters of the stream edge. One can tell by looking at the impact sites that a disturbance has occurred. Not all species are affected adversely, however. Possardt and Dodge (1978) found that certain species, such as shorebirds and swallows, increased in numbers due to an increase in favorable habitat and prey caused by the channelization. By evaluating these sites in a more objective manner, it is hoped the extent of the disturbance can be determined, as well as which species will be adversely affected.

Because black-capped chickadees are dependant on cavities and open forest habitats, these projects seem to affect their populations. It is apparent from the canopy, height, and food SI graphs that the mean chickadee density from this study (2.7 birds/ha) started appearing at sites with SI values of approximately 0.5. Based on these results, it is suggested the agencies involved in reviewing bridge replacement projects continue to minimize the extent of channelization that might occur and reduce the amount of riparian timber that is to be removed.

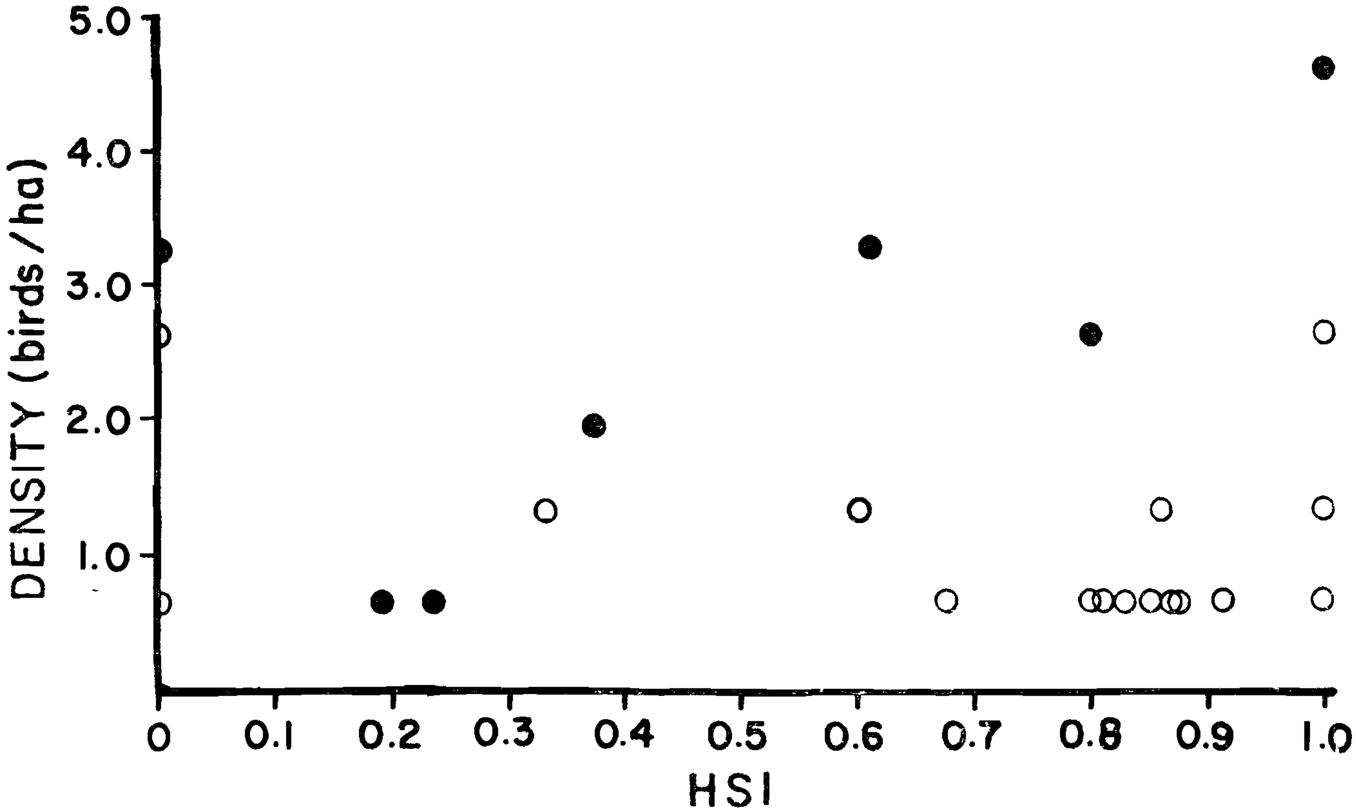
Downy Woodpecker

Possible discrepancies between observers in identifying downy woodpeckers may have occurred. One observer recorded 32 downy woodpeckers while the other sighted 16 each of the downy and hairy (P. villosus) woodpeckers. All sightings of both species were grouped together as a result. A total of 64 individual birds were sighted, representing 14 impact and 16 control sites. Downy sightings were few at all sites and the conversion to density yielded an unusual histogram for those censuses taken within the impacted area. This histogram was unusable for estimating densities because of the small detection distance. Instead, the mean detection distance of control sites (35 m) was used for all sites where downy/hairy woodpeckers were recorded. It was assumed the mean detection distance of the censuses taken within the impacted areas would be at least as large as those at controls because of the more open habitat; as was the case for chickadees. Densities were calculated for the downy woodpecker at 25 sites in which they were sighted within the 35 m detection distance, resulting in a mean of 1.4 birds/ha (Table 2).

Density vs HSI

As with the chickadee, there was little relationship between downy woodpecker abundance and HSI values ($r = -0.01$, Figure 10) using the 25 sites where density was estimated. Both the chi-square and the maximum density

Figure 10. Relationship between downy woodpecker densities (birds/ha) and HSI ($r = -0.01$, $P > 0.5$). Dark circles represent maximum density estimates used to evaluate the model's ability in predicting the upper limits of species response.



5.0
4.0
3.0
2.0
1.0
DENSITY (birds/ha)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
HSI

analyses performed poorly when comparing species response and HSI (Table 4). This is probably the result of the censuses, as well as the habitat sampling. Because downy woodpeckers often have large home ranges during the breeding season (Fitch 1958), and because of their lack of sociality (Short 1979), the data probably reflect patterns of habitat use and not true woodpecker abundance and response to habitat suitability. Assumptions relating frequency of use to habitat quality haven't been well tested (Lancia et al. 1986). To adequately assess the model, one would need to sample an area corresponding to the woodpeckers' home range. Had this been the case, this species probably would have been sighted at more sites representing a broader range of habitat suitability.

Table 4. Chi-square and regression analyses of the upper limits of the density-model output relationships for the downy woodpecker.

	Chi-square[a]				Regression[b]
Zone	I	II	III	IV	r
HSI	.18	.71	.89	.05	0.39 (P > 0.2)
Snag SI	.18	.71	.89	.05	0.18 (P > 0.5)
Basal area SI	>.5	---*	.17	.01	0.05 (P > 0.5)

[a] - G-statistic values

[b] - Regression of maximum density values for ten habitat quality classes. These statistics correspond to the dark circles found in figures 10, 11a, and 11b.

* - No observations in this zone.

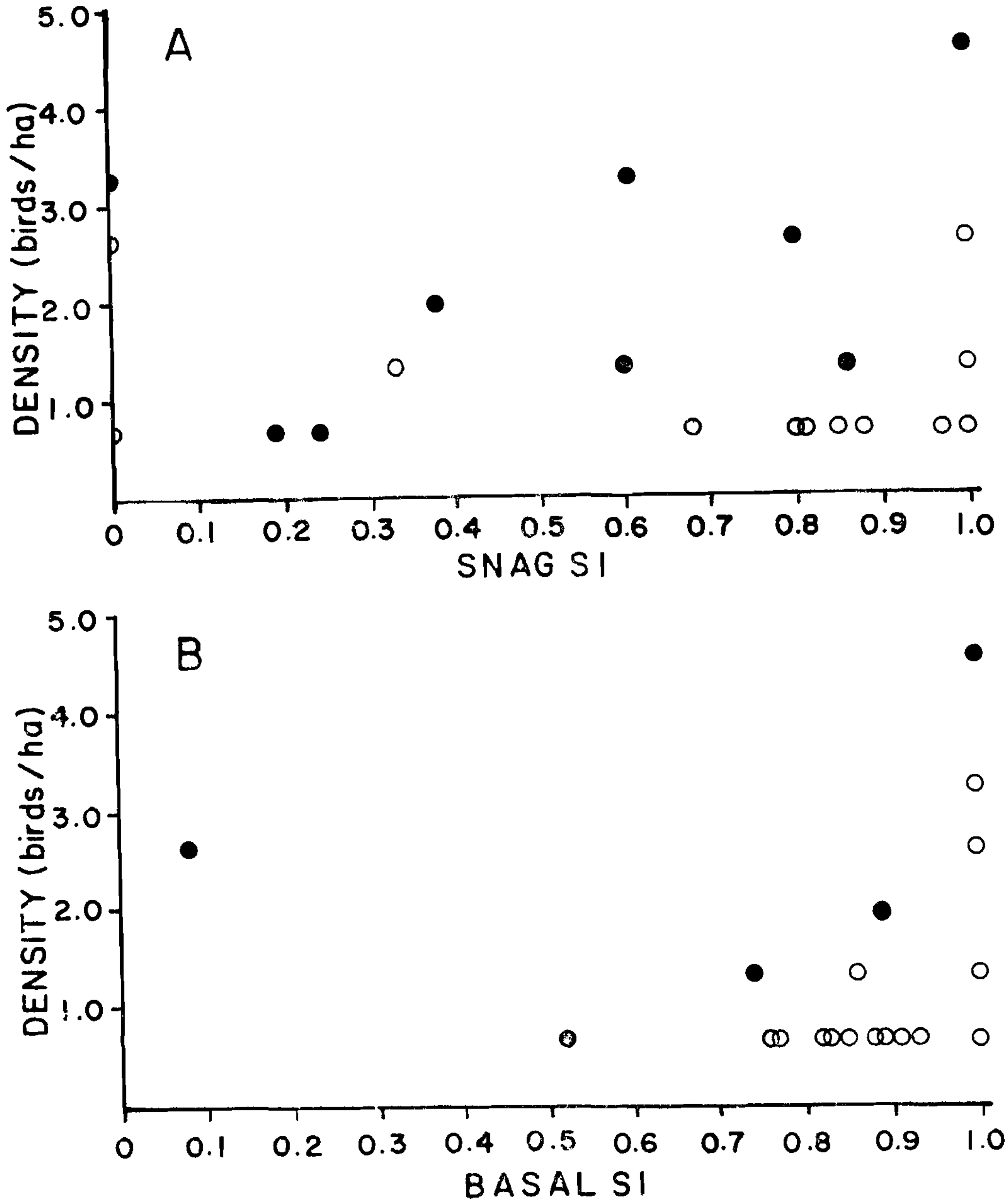
Of the undisturbed riparian cover types sampled, 62% were estimated as having greater than 15 snags/ha (Table 7). A site having over twelve snags per hectare is considered optimum for the reproduction component of the downy model. Sixteen of the 25 sites had snag densities greater than 12.5/ha (Table 8). Because of our sampling technique, areas with low densities of snags would not be sampled effectively, giving only low or high SI values. Downy woodpeckers are primary cavity-nesters and tend to excavate new holes yearly instead of reusing old ones (Short 1979). Consequently, the presence of cavities would not be a good estimator of nest site availability. As with the chickadee model, an addition of the number of suitable limb stubs in live trees and the decay class of nesting substrates might help "fine tune" the model. These distinctions could be relevant to cavity-nesting birds (Best and Stauffer 1986).

Density vs SI

For the downy woodpecker model, both basal area and snag density were poor predictors of abundance (Figures 11a and b, r = -0.03 and -0.02, respectively). The chi-square and maximum density analyses showed no relationship, either. Again, this probably reflects the area sampled because of the birds' home range and their scarcity, the method of determining snag availability, as well as observer confusion.

Figure 11. A: Relationship between downy woodpecker densities (birds/ha) and snag SI ($r = -0.02$, $P > 0.5$).

B: Relationship between downy woodpecker densities (birds/ha) and basal area SI ($r = 0.01$, $P > 0.5$). Dark circles, in both graphs, represent maximum density estimates used to evaluate the SI's ability in predicting the upper limits of species response.


A
DENSITY (birds/ha)
5.0
4.0
3.0
2.0
1.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
SNAG SI
B
DENSITY (birds/ha)
5.0
4.0
3.0
2.0
1.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
BASAL SI

SUMMARY

The use of models depicting species-habitat relationships for wildlife management decisions has become widespread. Without proper testing, this use can lead to erroneous conclusions about the assumed relationships. One problem with developing models to predict species-habitat relationships is that factors not included in the model, either individually or combined, may act to shape a species' response to its environment. These factors include such things as predation, dispersal, competition, and disease, among others. The use of habitats by a species may vary geographically and temporally, as well. Measures of species response such as density, habitat occupancy, and population size have also been criticized because they may not be true indicators of habitat suitability due to such things as site fidelity, dispersal, and recolonization. Parameters such as birth rate, death rate, dispersal rate, and overall fitness of the individuals have been suggested as better means of measuring species response.

Bird censusing and habitat sampling were conducted during the summer of 1988 at 25 impacted bridge construction sites and 25 control sites in eastern Kansas. Habitat Suitability Index models for the black-capped chickadee and downy woodpecker were used to test the ability of the model in predicting habitat change and bird abundance. Measures of model output were compared with estimates of species abundance to test the species-habitat relationships outlined

in each model. The effects of the resulting stream channelization were also determined based on the differences of the quality and quantity of habitat between impact and control sites.

Both chickadee and downy models failed to predict measures of species response when compared to measures of habitat. The average height of the overstory and percent canopy cover variables were the best predictors of chickadee abundance and of the upper limits of species response, suggesting that these variables, in part, limit the abundance of black-capped chickadees. This would suggest that the assumption concerning the positive relationship between chickadee densities and canopy volume, and thus, the assumed abundance of available food, appears to valid. There was no relationship between the density of snags and abundance. Snags, as defined in the model, were either abundant or not present at most sites. The method for sampling snag availability was inadequate because only cover type SI values of 0.0 or 1.0 resulted. A larger sampling area is needed to further examine the relationship between the reproduction component and chickadee abundance. Once this is accomplished, one can further test the relationship between abundance and HSI. The addition of decay classes of snags and the presence of suitable chickadee cavities would also be helpful in determining nesting limitations placed on the chickadee.

Black-capped chickadee densities were higher at control sites than at impact sites. Habitat units were also higher at the control sites. It would appear that chickadee populations are being affected; resulting from the apparent vegetation disturbance. By monitoring future construction sites using habitat models, the agencies involved can determine which species will be affected at different levels of impact.

Neither variable of the downy model was capable of predicting abundance or defining the upper limits of density at 25 sites where density was calculated. A larger sampling and census area would give a broader range of suitable habitats and increase the chances of sighting the downy because of its larger home range.

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LITERATURE CITED

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APPENDICES

APPENDIX A

HABITAT MEASUREMENTS AND MODEL OUTPUT FOR THE BLACK-CAPPED CHICKADEE

Table 5. Vegetation measurements and model output by transect (cover type) for the black-capped chickadee.

Site	Transect	Percent canopy	Canopy SI	Average height(m)	Height SI	Food SI[a]	Snags /ha	Snag SI	HSI[b]	Area (ha)
AL1115C	TL1	86.40	0.82	12.90	0.86	0.84	30.00	1.00	0.839	0.88
AL1115C	TR1	86.40	0.82	12.90	0.86	0.84	30.00	1.00	0.839	0.97
*AL1115T	TL1	9.80	0.20	20.10	1.00	0.44	0.00	0.00	0.000	0.01
AL1115T	TL2	86.40	0.82	12.90	0.86	0.84	30.00	1.00	0.839	0.06
AN1118C	TL1	93.80	0.70	29.35	1.00	0.84	40.00	1.00	0.836	1.22
AN1118C	TR1	93.80	0.70	29.35	1.00	0.84	40.00	1.00	0.836	2.20
*AN1118T	TL1	57.20	1.00	8.08	0.54	0.73	0.00	0.00	0.000	0.19
AN1118T	TL2	93.80	0.70	29.35	1.00	0.84	40.00	1.00	0.836	0.35
AN1118T	TR1	10.30	0.21	18.23	1.00	0.45	0.00	0.00	0.000	0.02
AN1118T	TR2	74.50	1.00	19.20	1.00	1.00	0.00	0.00	0.000	0.13
BB1614C	TL1	82.70	0.88	25.20	1.00	0.94	60.00	1.00	0.936	0.12
BB1614C	TR1	82.70	0.88	25.20	1.00	0.94	60.00	1.00	0.936	0.96
BB1614T	TL1	1.90	0.04	16.40	1.00	0.19	0.00	0.00	0.000	0.06
BB1614T	TL2	60.90	1.00	25.40	1.00	1.00	12.50	1.00	1.000	0.27
BB1614T	TR1	2.90	0.06	7.90	0.53	0.18	0.00	0.00	0.000	0.01
BB1614T	TR2	60.90	1.00	25.40	1.00	1.00	12.50	1.00	1.000	0.86
BU1715C	TL1	85.90	0.83	10.08	0.67	0.74	80.00	1.00	0.745	0.19
BU1715C	TR1	86.40	0.82	10.67	0.71	0.76	70.00	1.00	0.763	0.28
BU1715T	TL1	42.30	0.85	29.30	1.00	0.92	20.00	1.00	0.920	0.13
BU1715T	TL2	85.50	0.83	18.00	1.00	0.91	14.25	1.00	0.912	0.25
BU1715T	TR1	0.00	0.00	2.97	0.20	0.00	0.00	0.00	0.000	0.07
CS2612C	TL1	54.90	1.00	24.00	1.00	1.00	60.00	1.00	1.000	0.38
CS2612C	TR1	84.00	0.86	25.12	1.00	0.93	10.00	1.00	0.925	0.88
CS2612T	TL1	79.90	0.92	30.12	1.00	0.96	0.00	0.00	0.000	0.75
CS2612T	TR1	80.60	0.91	19.45	1.00	0.95	10.00	1.00	0.954	1.51
DG1166C	TL1	90.80	0.75	19.60	1.00	0.86	20.00	1.00	0.864	1.26
DG1166C	TR1	90.80	0.75	19.60	1.00	0.86	20.00	1.00	0.864	1.26
*DG1166T	TL1	16.90	0.34	15.10	1.00	0.58	0.00	0.00	0.000	0.05
DG1166T	TL2	90.80	0.75	19.60	1.00	0.86	20.00	1.00	0.864	0.24
DG1166T	TR1	16.90	0.34	15.10	1.00	0.58	0.00	0.00	0.000	0.05
DG1166T	TR2	90.80	0.75	19.60	1.00	0.86	20.00	1.00	0.864	0.24
DK1136C	TL1	77.00	0.97	11.69	0.78	0.87	30.00	1.00	0.869	0.66
DK1136C	TR1	77.00	0.97	11.69	0.78	0.87	30.00	1.00	0.869	0.28
*DK1136T	TL1	0.00	0.00	3.25	0.22	0.00	0.00	0.00	0.000	0.06
DK1136T	TL2	77.00	0.97	11.69	0.78	0.87	30.00	1.00	0.869	0.06
DK1136T	TR1	0.00	0.00	3.25	0.22	0.00	0.00	0.00	0.000	0.11
DK1136T	TR2	77.00	0.97	11.69	0.78	0.87	30.00	1.00	0.869	0.10
DK1138C	TL1	83.20	0.87	20.05	1.00	0.93	60.00	1.00	0.932	0.13
DK1138C	TR1	83.20	0.87	20.05	1.00	0.93	60.00	1.00	0.932	0.66
*DK1138T	TL1	1.60	0.03	5.49	0.37	0.11	0.00	0.00	0.000	0.19
DK1138T	TR1	36.90	0.74	11.18	0.75	0.74	12.50	1.00	0.742	0.06
DK1138T	TR2	83.20	0.87	20.05	1.00	0.93	60.00	1.00	0.932	0.38
FR0845C	TL1	98.00	0.63	13.42	0.89	0.75	0.00	0.00	0.000	0.12
FR0845C	TR1	98.00	0.63	13.42	0.89	0.75	0.00	0.00	0.000	0.36
FR0845T	TL1	13.80	0.28	5.08	0.34	0.31	0.00	0.00	0.000	0.20
FR0845T	TL2	92.40	0.76	31.20	1.00	0.85	40.00	1.00	0.849	0.76
FR0845T	TR1	13.80	0.28	5.08	0.34	0.31	0.00	0.00	0.000	0.09
FR0845T	TR2	92.40	0.72	31.20	1.00	0.85	40.00	1.00	0.849	0.05
FR1758C	TL1	89.80	0.76	34.53	1.00	0.87	20.00	1.00	0.874	0.36
FR1758C	TR1	89.80	0.76	34.53	1.00	0.87	20.00	1.00	0.874	2.25

Table 5. Continued.

Site	Transect	Percent canopy	Canopy SI	Average height(m)	Height SI	Food SI[a]	Snags /ha	Snag SI	HSI[b]	Area (ha)
FR1758T	TL1	2.00	0.04	18.60	1.00	0.20	0.00	0.00	0.000	0.08
FR1758T	TL2	86.00	0.82	20.31	1.00	0.91	80.00	1.00	0.908	1.38
FR1758T	TR1	2.00	0.04	18.60	1.00	0.20	0.00	0.00	0.000	0.08
FR1758T	TR2	86.00	0.82	20.31	1.00	0.91	80.00	1.00	0.908	1.97
FR1951C	TL1	79.00	0.94	39.30	1.00	0.97	0.00	0.00	0.000	0.48
FR1951C	TR1	79.00	0.94	39.30	1.00	0.97	0.00	0.00	0.000	0.42
FR1951T	TL1	10.10	0.20	18.80	1.00	0.45	0.00	0.00	0.000	0.07
FR1951T	TL3	59.70	1.00	22.85	1.00	1.00	0.00	0.00	0.000	1.32
FR1951T	TR1	10.10	0.20	18.80	1.00	0.45	0.00	0.00	0.000	0.05
GE1564C	TL1	68.80	1.00	8.80	0.59	0.77	10.00	1.00	0.766	0.13
GE1564C	TR1	97.10	0.65	12.50	0.83	0.73	0.00	0.00	0.000	0.31
*GE1564T	TL1	0.00	0.00	3.25	0.22	0.00	0.00	0.00	0.000	0.03
GE1564T	TL2	68.80	1.00	8.80	0.59	0.77	4.00	1.00	0.766	0.16
GE1564T	TR1	6.50	0.13	12.50	0.83	0.33	0.00	0.00	0.000	0.03
GE1564T	TR2	97.10	0.65	12.50	0.83	0.73	0.00	0.00	0.000	0.44
GW1650C	TL1	94.90	0.68	19.95	1.00	0.83	50.00	1.00	0.826	0.48
GW1650C	TR1	94.90	0.68	19.95	1.00	0.83	50.00	1.00	0.826	0.24
GW1650T	TL1	67.90	1.00	31.43	1.00	1.00	10.00	1.00	1.000	0.96
GW1650T	TR1	67.90	1.00	31.43	1.00	1.00	10.00	1.00	1.000	1.38
JA0400C	TL1	93.30	0.71	17.61	1.00	0.84	0.00	0.00	0.000	0.63
JA0400C	TR1	90.30	0.76	29.00	1.00	0.87	10.00	1.00	0.869	1.00
*JA0400T	TL1	0.00	0.00	8.57	0.57	0.00	0.00	0.00	0.000	0.09
JA0400T	TL2	93.30	0.71	17.61	1.00	0.84	0.00	0.00	0.000	0.32
JA0400T	TR1	39.80	0.80	12.85	0.86	0.83	0.00	0.00	0.000	0.01
JA0400T	TR2	90.30	0.76	29.00	1.00	0.87	10.00	1.00	0.869	0.21
JF0888C	TL1	78.30	0.95	19.06	1.00	0.97	0.00	0.00	0.000	0.12
JF0888C	TR1	78.30	0.95	19.06	1.00	0.97	0.00	0.00	0.000	1.14
JF0888T	TL1	4.10	0.08	18.60	1.00	0.29	0.00	0.00	0.000	0.17
JF0888T	TR1	76.80	0.97	14.73	0.98	0.98	0.00	0.00	0.000	0.18
JF1664C	TL1	72.80	1.00	24.90	1.00	1.00	30.00	1.00	1.000	0.18
JF1664C	TR1	72.80	1.00	24.90	1.00	1.00	30.00	1.00	1.000	0.18
*JF1664T	TL1	3.00	0.06	5.33	0.36	0.15	0.00	0.00	0.000	0.04
JF1664T	TL2	72.80	1.00	24.90	1.00	1.00	30.00	1.00	1.000	0.06
JF1664T	TR1	3.00	0.06	5.33	0.36	0.15	0.00	0.00	0.000	0.07
JF1664T	TR2	72.80	1.00	24.90	1.00	1.00	30.00	1.00	1.000	0.72
MN1510C	TL1	91.50	0.74	17.03	1.00	0.86	20.00	1.00	0.858	0.42
MN1510C	TR1	91.50	0.74	17.03	1.00	0.86	20.00	1.00	0.858	0.16
MN1510T	TL1	18.60	0.37	10.67	0.71	0.51	0.00	0.00	0.000	0.06
MN1510T	TL2	72.20	1.00	13.63	0.91	0.95	40.00	1.00	0.953	1.19
MN1510T	TR1	18.60	0.37	10.67	0.71	0.51	0.00	0.00	0.000	0.03
MN1510T	TR2	72.20	1.00	13.63	0.91	0.95	40.00	1.00	0.953	0.22
OS0620C	TL1	77.70	0.96	14.90	0.99	0.97	10.00	1.00	0.975	0.41
OS0620C	TR1	69.60	1.00	29.60	1.00	1.00	0.00	0.00	0.000	1.32
OS0620T	TL1	19.60	0.39	5.73	0.38	0.39	0.00	0.00	0.000	0.10
OS0620T	TR1	9.00	0.18	7.82	0.52	0.31	0.00	0.00	0.000	0.10
SN0680C	TL1	99.60	0.61	26.60	1.00	0.78	80.00	1.00	0.779	0.54
SN0680C	TR1	99.60	0.61	26.60	1.00	0.78	80.00	1.00	0.779	0.78
SN0680T	TL1	31.50	0.63	6.07	0.40	0.50	0.00	0.00	0.000	0.05
SN0680T	TR1	49.60	0.99	24.65	1.00	1.00	30.00	1.00	0.996	1.62

Table 5. Continued.

Site	Transect	Percent canopy	Canopy SI	Average height(m)	Height SI	Food SI[a]	Snags /ha	Snag SI	HSI[b]	Area (ha)
SN1099C	TL1	88.40	0.79	29.40	1.00	0.89	30.00	1.00	0.886	0.12
SN1099C	TR1	88.40	0.79	29.40	1.00	0.89	30.00	1.00	0.886	0.78
*SN1099T	TL1	0.00	0.00	3.53	0.24	0.00	0.00	0.00	0.000	0.04
SN1099T	TR1	0.00	0.00	1.83	0.12	0.00	0.00	0.00	0.000	0.07
SN1099T	TR2	88.40	0.79	29.40	1.00	0.89	30.00	1.00	0.886	0.84
WB0919C	TL1	46.40	0.93	22.30	1.00	0.96	20.00	1.00	0.963	1.08
WB0919C	TR1	67.40	1.00	20.17	1.00	1.00	10.00	1.00	1.000	2.25
*WB0919T	TL1	39.20	0.78	14.60	0.97	0.87	10.00	1.00	0.874	0.12
WB0919T	TL2	46.40	0.93	22.30	1.00	0.96	20.00	1.00	0.963	0.24
WB0919T	TR1	17.50	0.35	29.60	1.00	0.59	0.00	0.00	0.000	0.04
WB0919T	TR2	67.40	1.00	20.17	1.00	1.00	10.00	1.00	1.000	0.24
WB1583C	TL1	61.50	1.00	22.60	1.00	1.00	30.00	1.00	1.000	0.30
WB1583C	TR1	86.30	0.82	16.45	1.00	0.91	0.00	0.00	0.000	0.83
*WB1583T	TL1	16.08	0.34	21.60	1.00	0.58	0.00	0.00	0.000	0.11
WB1583T	TL2	61.50	1.00	22.60	1.00	1.00	30.00	1.00	1.000	1.02
WB1583T	TR1	89.20	0.77	21.60	1.00	0.88	0.00	0.00	0.000	0.11
WB1583T	TR2	86.30	0.82	16.45	1.00	0.91	0.00	0.00	0.000	0.96
WL1840C	TL1	100.00	0.60	20.92	1.00	0.77	30.00	1.00	0.775	0.46
WL1840C	TR1	100.00	0.60	20.92	1.00	0.77	30.00	1.00	0.775	0.46
*WL1840T	TL1	8.80	0.18	17.40	1.00	0.42	60.00	1.00	0.420	0.01
WL1840T	TL2	100.00	0.60	20.92	1.00	0.77	30.00	1.00	0.775	0.23
WL1840T	TR1	8.80	0.18	17.40	1.00	0.42	60.00	1.00	0.420	0.02
WL1840T	TR2	100.00	0.60	20.92	1.00	0.77	30.00	1.00	0.775	0.08
WO0884C	TL1	99.20	0.61	14.95	1.00	0.78	30.00	1.00	0.782	1.56
WO0884C	TR1	99.20	0.61	14.95	1.00	0.78	30.00	1.00	0.782	1.68
WO0884T	TL1	8.10	0.16	5.21	0.35	0.24	0.00	0.00	0.000	0.11
WO0884T	TL2	87.40	0.80	25.60	1.00	0.90	0.00	0.00	0.000	0.73
WO0884T	TR1	8.10	0.16	5.21	0.35	0.24	0.00	0.00	0.000	0.13
WO0884T	TR2	87.40	0.80	25.60	1.00	0.90	0.00	0.00	0.000	0.30
WO1581C	TL1	90.50	0.75	16.10	1.00	0.87	40.00	1.00	0.867	0.62
WO1581C	TR1	90.50	0.75	16.10	1.00	0.87	40.00	1.00	0.867	1.88
*WO1581T	TL1	36.50	0.73	13.80	0.92	0.82	0.00	0.00	0.000	0.16
WO1581T	TL2	61.60	1.00	23.20	1.00	1.00	0.00	0.00	0.000	0.14
WO1581T	TR1	24.60	0.49	10.68	0.92	0.59	60.00	1.00	0.592	0.01
WO1581T	TR2	90.50	0.75	16.10	1.00	0.87	40.00	1.00	0.867	0.90

* - Impact sites where mature riparian timber beyond the impacted area was assumed to be equal that of the corresponding control.
[a] - Geometric mean of canopy SI and height SI.
[b] - Minimum between the food SI and snag SI.

Table 6. Variable estimates and model output for the black-capped chickadee.*

Site	Percent canopy	Canopy SI	Height (m)	Height SI	Food SI	Snags /ha	Snag SI	HSI	Area (ha)	Habitat units[a]	Density[b]
AL1115C	86.40	0.82	12.90	0.86	0.84	30.00	1.00	0.839	1.85	1.552	2.49
AL1115T	75.46	0.73	13.93	0.88	0.78	25.71	0.86	0.719	0.07	0.050	0.00
AN1118C	93.80	0.70	29.35	1.00	0.84	40.00	1.00	0.836	3.42	2.859	3.48
AN1118T	77.67	0.82	21.26	0.87	0.83	20.29	0.51	0.424	0.69	0.293	4.08
BB1614C	82.70	0.88	25.20	1.00	0.94	60.00	1.00	0.936	1.08	1.011	0.00
BB1614T	57.47	0.94	24.80	1.00	0.95	11.78	0.94	0.942	1.20	1.130	1.81
BU1715C	86.20	0.82	10.43	0.69	0.75	74.04	1.00	0.755	0.47	0.355	1.19
BU1715T	59.72	0.71	18.93	0.88	0.77	13.69	0.84	0.772	0.45	0.347	0.00
CS2612C	75.22	0.90	24.78	1.00	0.95	25.08	1.00	0.948	1.26	1.194	1.49
CS2612T	80.37	0.91	22.99	1.00	0.95	6.68	0.67	0.638	2.26	1.442	1.32
DG1166C	90.80	0.75	19.60	1.00	0.86	20.00	1.00	0.864	2.52	2.177	2.98
DG1166T	78.06	0.68	18.82	1.00	0.81	16.55	0.83	0.715	0.58	0.415	2.99
DK1136C	77.00	0.97	11.69	0.78	0.87	30.00	1.00	0.869	0.94	0.817	3.98
DK1136T	37.33	0.47	7.34	0.49	0.42	14.55	0.48	0.421	0.33	0.139	2.31
DK1138C	83.20	0.87	20.05	1.00	0.93	60.00	1.00	0.932	0.79	0.736	1.00
DK1138T	54.18	0.60	14.81	0.79	0.66	37.38	0.70	0.633	0.63	0.399	2.63
FR0845C	98.00	0.63	13.42	0.89	0.75	0.00	0.00	0.000	0.48	0.000	1.99
FR0845T	71.68	0.63	24.31	0.83	0.71	29.45	0.74	0.626	1.10	0.689	4.12
FR1758C	89.80	0.76	34.52	1.00	0.87	20.00	1.00	0.874	2.61	2.281	3.98
FR1758T	82.17	0.78	20.24	1.00	0.88	76.35	0.95	0.866	3.51	3.040	0.32
FR1951C	79.00	0.94	39.30	1.00	0.97	0.00	0.00	0.000	0.90	0.000	7.96
FR1951T	55.57	0.93	22.51	1.00	0.95	0.00	0.00	0.000	1.44	0.000	1.49
GE1564C	88.74	0.75	11.41	0.76	0.74	2.95	0.30	0.226	0.44	0.099	4.98
GE1564T	81.71	0.68	11.18	0.74	0.69	0.97	0.24	0.186	0.66	0.123	1.59
GW1650C	94.90	0.68	19.95	1.00	0.83	50.00	1.00	0.826	0.72	0.595	1.49
GW1650T	67.90	1.00	31.43	1.00	1.00	10.00	1.00	1.000	2.34	2.340	2.87
JA0400C	91.46	0.74	24.60	1.00	0.86	6.13	0.61	0.533	1.63	0.869	7.46
JA0400T	78.12	0.63	20.04	0.94	0.73	3.33	0.33	0.289	0.63	0.182	2.99
JF0888C	78.30	0.95	19.06	1.00	0.97	0.00	0.00	0.000	1.26	0.000	1.00
JF0888T	41.49	0.54	16.61	0.99	0.64	0.00	0.00	0.000	0.35	0.000	0.64
JF1664C	72.80	1.00	24.90	1.00	1.00	30.00	1.00	1.000	0.36	0.360	3.98
JF1664T	64.17	0.88	22.48	0.92	0.89	26.29	0.88	0.876	0.89	0.780	1.00
MN1510C	91.50	0.74	17.03	1.00	0.86	20.00	1.00	0.858	0.58	0.498	2.49
MN1510T	68.99	0.96	13.45	0.90	0.92	37.60	0.94	0.896	1.50	1.344	2.95
OS0620C	71.52	0.99	26.12	1.00	0.99	2.37	0.24	0.231	1.73	0.400	1.49
OS0620T	14.30	0.29	6.78	0.45	0.35	0.00	0.00	0.000	0.20	0.000	0.32
SN0680C	99.60	0.61	26.60	1.00	0.78	80.00	1.00	0.779	1.32	1.028	4.48
SN0680T	49.06	0.98	24.09	0.98	0.99	29.10	0.97	0.966	1.67	1.613	3.12
SN1099C	88.40	0.79	29.40	1.00	0.89	30.00	1.00	0.866	0.90	0.779	3.48
SN1099T	78.16	0.70	26.28	0.90	0.79	26.53	0.88	0.784	0.95	0.745	2.49
WB0919C	60.59	0.98	20.86	1.00	0.99	13.24	1.00	0.988	3.33	3.290	3.48
WB0919T	51.12	0.89	20.51	0.99	0.94	13.13	0.94	0.900	0.64	0.576	4.72
WB1583C	79.72	0.87	18.08	1.00	0.93	7.96	0.27	0.265	1.13	0.299	5.47
WB1583T	71.44	0.88	19.82	1.00	0.93	13.91	0.46	0.464	2.20	1.021	4.26
WL1840C	100.00	0.60	20.92	1.00	0.77	30.00	1.00	0.775	0.92	0.713	5.47
WL1840T	91.95	0.56	20.61	1.00	0.74	32.65	1.00	0.743	0.34	0.253	0.82
WO0884C	99.20	0.61	14.95	1.00	0.78	30.00	1.00	0.782	3.24	2.534	2.98
WO0884T	72.41	0.68	21.75	0.88	0.78	0.00	0.00	0.000	1.27	0.000	4.58
WO1581C	90.50	0.75	16.10	1.00	0.87	40.00	1.00	0.867	2.50	2.168	2.98
WO1581T	79.47	0.77	16.57	0.99	0.88	30.25	0.75	0.650	1.21	0.787	1.49

* - Variable estimates and model output values are weighted averages based on the areas of cover types found in Table 5. Thus, SI values may not correspond to variable estimates and HSI values may not correspond to the lowest value between the food SI and snag SI.

[a] - HSI * area.

[b] - birds/ha.

APPENDIX B

HABITAT MEASUREMENTS AND MODEL OUTPUT

FOR THE DOWNY WOODPECKER

Table 7. Vegetation measurements and model output by transect (cover type) for the downy woodpecker.

Site	Transect	Basal Area	Basal SI	Snags /ha	Snag SI	Area (ha)	HSI[a]
AL1115C	TL1	18.25	1.00	30.00	1.00	0.88	1.000
AL1115C	TR1	18.25	1.00	30.00	1.00	0.97	1.000
*AL1115T	TL1	0.46	0.05	0.00	0.00	0.01	0.000
AL1115T	TL2	18.25	1.00	30.00	1.00	0.06	1.000
AN1118C	TL1	21.47	0.93	10.00	0.80	1.22	0.800
AN1118C	TR1	21.47	0.93	10.00	0.80	2.20	0.800
*AN1118T	TL1	4.82	0.48	0.00	0.00	0.19	0.000
AN1118T	TL2	21.47	0.93	10.00	0.80	0.35	0.800
AN1118T	TR1	6.89	0.69	0.00	0.00	0.02	0.000
AN1118T	TR2	12.63	1.00	0.00	0.00	0.13	0.000
BB1614C	TL1	15.61	1.00	30.00	1.00	0.12	1.000
BB1614C	TR1	15.61	1.00	30.00	1.00	0.96	1.000
BB1614T	TL1	2.68	0.27	0.00	0.00	0.06	0.000
BB1614T	TL2	15.07	1.00	0.00	0.00	0.27	0.000
BB1614T	TR1	1.15	0.12	50.00	1.00	0.01	0.115
BB1614T	TR2	15.07	1.00	0.00	0.00	0.86	0.000
BU1715C	TL1	13.89	1.00	50.00	1.00	0.19	1.000
BU1715C	TR1	12.74	1.00	40.00	1.00	0.28	1.000
BU1715T	TL1	5.17	0.52	20.00	1.00	0.13	0.517
BU1715T	TL2	10.45	1.00	0.00	0.00	0.25	0.000
BU1715T	TR1	0.92	0.09	0.00	0.00	0.07	0.000
CS2612C	TL1	14.01	1.00	30.00	1.00	0.38	1.000
CS2612C	TR1	16.19	1.00	10.00	0.80	0.88	0.800
CS2612T	TL1	19.75	1.00	30.00	1.00	0.75	1.000
CS2612T	TR1	18.48	1.00	10.00	0.80	1.51	0.800
DG1166C	TL1	23.42	0.83	30.00	1.00	1.26	0.829
DG1166C	TR1	23.42	0.83	30.00	1.00	1.26	0.829
*DG1166T	TL1	0.92	0.09	0.00	0.00	0.05	0.000
DG1166T	TL2	23.42	0.83	30.00	1.00	0.24	0.829
DG1166T	TR1	0.92	0.09	0.00	0.00	0.05	0.000
DG1166T	TR2	23.42	0.83	30.00	1.00	0.24	0.829
DK1136C	TL1	23.88	0.81	0.00	0.00	0.66	0.000
DK1136C	TR1	23.88	0.81	0.00	0.00	0.28	0.000
*DK1136T	TL1	3.44	0.34	0.00	0.00	0.06	0.000
DK1136T	TL2	23.88	0.81	0.00	0.00	0.06	0.000
DK1136T	TR1	3.44	0.34	0.00	0.00	0.11	0.000
DK1136T	TR2	23.88	0.81	0.00	0.00	0.10	0.000
DK1138C	TL1	14.01	1.00	60.00	1.00	0.13	1.000
DK1138C	TR1	14.01	1.00	60.00	1.00	0.66	1.000
*DK1138T	TL1	2.30	0.23	0.00	0.00	0.19	0.000
DK1138T	TR1	7.46	0.75	0.00	0.00	0.06	0.000
DK1138T	TR2	14.01	1.00	60.00	1.00	0.38	1.000
FR0845C	TL1	14.69	1.00	0.00	0.00	0.12	0.000
FR0845C	TR1	14.69	1.00	0.00	0.00	0.36	0.000
FR0845T	TL1	1.15	0.12	0.00	0.00	0.20	0.000
FR0845T	TL2	14.92	1.00	0.00	0.00	0.76	0.000
FR0845T	TR1	1.15	0.12	0.00	0.00	0.09	0.000
FR0845T	TR2	14.92	1.00	0.00	0.00	0.05	0.000

Table 7. Continued.

Site	Transect	Basal Area	Basal SI	Snags /ha	Snag SI	Area (ha)	HSI[a]
FR1758C	TL1	16.88	1.00	20.00	1.00	0.36	1.000
FR1758C	TR1	16.88	1.00	20.00	1.00	2.25	1.000
FR1758T	TL1	1.15	0.12	0.00	0.00	0.08	0.000
FR1758T	TL2	18.94	1.00	80.00	1.00	1.38	1.000
FR1758T	TR1	1.15	0.12	0.00	0.00	0.08	0.000
FR1758T	TR2	18.94	1.00	80.00	1.00	1.97	1.000
FR1951C	TL1	15.27	1.00	20.00	1.00	0.48	1.000
FR1951C	TR1	15.27	1.00	20.00	1.00	0.42	1.000
FR1951T	TL1	0.69	0.07	0.00	0.00	0.07	0.000
FR1951T	TL3	21.81	0.91	0.00	0.00	1.32	0.000
FR1951T	TR1	0.69	0.07	0.00	0.00	0.05	0.000
GE1564C	TL1	9.41	0.94	10.00	0.80	0.13	0.800
GE1564C	TR1	24.57	0.77	0.00	0.00	0.31	0.000
*GE1564T	TL1	1.38	0.14	0.00	0.00	0.03	0.000
GE1564T	TL2	9.41	0.94	10.00	0.80	0.16	0.800
GE1564T	TR1	2.98	0.30	0.00	0.00	0.03	0.000
GE1564T	TR2	24.57	0.77	0.00	0.00	0.44	0.000
GW1650C	TL1	18.14	1.00	50.00	1.00	0.48	1.000
GW1650C	TR1	18.14	1.00	50.00	1.00	0.24	1.000
GW1650T	TL1	12.86	1.00	50.00	1.00	0.96	1.000
GW1650T	TR1	12.86	1.00	50.00	1.00	1.38	1.000
JA0400C	TL1	15.15	1.00	0.00	0.00	0.63	0.000
JA0400C	TR1	14.92	1.00	30.00	1.00	1.00	1.000
*JA0400T	TL1	0.57	0.06	0.00	0.00	0.09	0.000
JA0400T	TL2	15.15	1.00	0.00	0.00	0.32	0.000
JA0400T	TR1	4.59	0.46	0.00	0.00	0.01	0.000
JA0400T	TR2	14.92	1.00	30.00	1.00	0.21	1.000
JF0888C	TL1	13.32	1.00	10.00	0.80	0.12	0.800
JF0888C	TR1	13.32	1.00	10.00	0.80	1.14	0.800
JF0888T	TL1	1.61	0.16	0.00	0.00	0.17	0.000
JF0888T	TR1	8.61	0.86	0.00	0.00	0.18	0.000
JF1664C	TL1	11.02	1.00	50.00	1.00	0.18	1.000
JF1664C	TR1	11.02	1.00	50.00	1.00	0.18	1.000
*JF1664T	TL1	0.69	0.07	0.00	0.00	0.04	0.000
JF1664T	TL2	11.02	1.00	50.00	1.00	0.06	1.000
JF1664T	TR1	0.69	0.07	0.00	0.00	0.07	0.000
JF1664T	TR2	11.02	1.00	50.00	1.00	0.72	1.000
MN1510C	TL1	15.73	1.00	30.00	1.00	0.42	1.000
MN1510C	TR1	15.73	1.00	30.00	1.00	0.16	1.000
MN1510T	TL1	1.84	0.18	10.00	0.80	0.06	0.184
MN1510T	TL2	16.07	1.00	20.00	1.00	1.19	1.000
MN1510T	TR1	1.84	0.18	10.00	0.80	0.03	0.184
MN1510T	TR2	16.07	1.00	20.00	1.00	0.22	1.000
OS0620C	TL1	10.56	1.00	10.00	0.80	0.41	0.800
OS0620C	TR1	13.78	1.00	0.00	0.00	1.32	0.000
OS0620T	TL1	0.92	0.09	0.00	0.00	0.10	0.000
OS0620T	TR1	0.69	0.07	0.00	0.00	0.10	0.000
SN0680C	TL1	19.37	1.00	40.00	1.00	0.54	1.000
SN0680C	TR1	19.37	1.00	40.00	1.00	0.78	1.000

Table 7. Continued.

Site	Transect	Basal Area	Basal SI	Snags /ha	Snag SI	Area (ha)	HSI[a]
SN0680T	TL1	1.61	0.16	0.00	0.00	0.05	0.000
SN0680T	TR1	8.95	0.90	30.00	1.00	1.62	0.895
SN1099C	TL1	22.62	0.90	20.00	1.00	0.12	0.869
SN1099C	TR1	22.62	0.90	20.00	1.00	0.78	0.869
*SN1099T	TL1	0.23	0.02	0.00	0.00	0.04	0.000
SN1099T	TR1	0.00	0.00	0.00	0.00	0.07	0.000
SN1099T	TR2	22.62	0.90	20.00	1.00	0.84	0.869
WB0919C	TL1	9.87	0.99	0.00	0.00	1.08	0.000
WB0919C	TR1	17.45	1.00	40.00	1.00	2.25	1.000
*WB0919T	TL1	6.43	0.64	0.00	0.00	0.12	0.000
WB0919T	TL2	9.87	0.99	0.00	0.00	0.24	0.000
WB0919T	TR1	3.90	0.39	0.00	0.00	0.04	0.000
WB0919T	TR2	17.45	1.00	40.00	1.00	0.24	1.000
WB1583C	TL1	11.37	1.00	40.00	1.00	0.30	1.000
WB1583C	TR1	17.34	1.00	10.00	0.80	0.83	0.800
*WB1583T	TL1	4.02	0.40	0.00	0.00	0.11	0.000
WB1583T	TL2	11.37	1.00	40.00	1.00	1.02	1.000
WB1583T	TR1	8.04	0.80	20.00	1.00	0.11	0.804
WB1583T	TR2	17.34	1.00	10.00	0.80	0.96	0.800
WL1840C	TL1	21.70	0.91	30.00	1.00	0.46	0.915
WL1840C	TR1	21.70	0.91	30.00	1.00	0.46	0.915
*WL1840T	TL1	1.15	0.12	40.00	1.00	0.01	0.115
WL1840T	TL2	21.70	0.91	30.00	1.00	0.23	0.915
WL1840T	TR1	1.15	0.12	40.00	1.00	0.02	0.115
WL1840T	TR2	21.70	0.91	30.00	1.00	0.08	0.915
WO0884C	TL1	17.22	1.00	30.00	1.00	1.56	1.000
WO0884C	TR1	17.22	1.00	30.00	1.00	1.68	1.000
WO0884T	TL1	2.07	0.20	0.00	0.00	0.11	0.000
WO0884T	TL2	15.50	1.00	40.00	1.00	0.73	1.000
WO0884T	TR1	2.07	0.20	0.00	0.00	0.13	0.000
WO0884T	TR2	15.50	1.00	40.00	1.00	0.30	1.000
WO1581C	TL1	19.63	1.00	30.00	1.00	0.62	1.000
WO1581C	TR1	19.63	1.00	30.00	1.00	1.88	1.000
*WO1581T	TL1	5.74	0.57	0.00	0.00	0.16	0.000
WO1581T	TL2	12.05	1.00	20.00	1.00	0.14	1.000
WO1581T	TR1	2.87	0.29	20.00	1.00	0.01	0.287
WO1581T	TR2	19.63	1.00	30.00	1.00	0.90	1.000

* - Impact sites where mature riparian timber beyond the impacted area was assumed to be equal that of the corresponding control.

a - Minimum SI between basal area and snags/ha.

Table 8. Variable estimates and model output for the downy woodpecker.*

Site	Basal area	Basal SI	Snags /ha	Snag SI	HSI	Area (ha)	Habitat units[a]	Density[b]
AL1115C	18.25	1.00	30.00	1.00	1.000	1.85	1.850	0.00
AL1115T	15.71	0.86	25.71	0.86	0.857	0.07	0.060	0.00
AN1118C	21.47	0.93	10.00	0.80	0.800	3.42	2.736	0.65
AN1118T	14.80	0.81	5.07	0.41	0.406	0.69	0.280	0.00
BB1614C	15.61	1.00	30.00	1.00	1.000	1.08	1.080	0.00
BB1614T	14.33	0.96	0.42	0.01	0.001	1.20	0.001	0.00
BU1715C	13.21	1.00	44.04	1.00	1.000	0.47	0.470	0.00
BU1715T	7.44	0.72	5.78	0.29	0.149	0.45	0.067	0.00
CS2612C	15.53	1.00	16.03	0.86	0.860	1.26	1.084	1.30
CS2612T	18.90	1.00	16.64	0.87	0.866	2.26	1.957	0.00
DG1166C	23.42	0.83	30.00	1.00	0.829	2.52	2.089	0.65
DG1166T	19.53	0.70	24.83	0.83	0.686	0.58	0.398	0.00
DK1136C	23.88	0.81	0.00	0.00	0.000	0.94	0.000	0.00
DK1136T	13.36	0.57	0.00	0.00	0.000	0.33	0.000	0.00
DK1138C	14.01	1.00	60.00	1.00	1.000	0.79	0.790	0.00
DK1138T	9.86	0.74	36.19	0.60	0.603	0.63	0.380	1.30
FR0845C	14.69	1.00	0.00	0.00	0.000	0.48	0.000	3.25
FR0845T	11.29	0.77	0.00	0.00	0.000	1.10	0.000	0.65
FR1758C	16.88	1.00	20.00	1.00	1.000	2.61	2.610	0.00
FR1758T	18.13	0.96	76.35	0.95	0.954	3.51	3.349	0.00
FR1951C	15.27	1.00	20.00	1.00	1.000	0.90	0.900	2.60
FR1951T	20.05	0.84	0.00	0.00	0.000	1.44	0.000	0.00
GE1564C	20.09	0.82	2.95	0.24	0.236	0.44	0.104	0.65
GE1564T	18.86	0.76	2.42	0.19	0.194	0.66	0.128	0.65
GW1650C	18.14	1.00	50.00	1.00	1.000	0.72	0.720	0.00
GW1650T	12.86	1.00	50.00	1.00	1.000	2.34	2.340	0.65
JA0400C	15.01	1.00	18.40	0.61	0.613	1.63	0.999	3.25
JA0400T	12.83	0.86	10.00	0.33	0.333	0.63	0.210	1.30
JF0888C	13.32	1.00	10.00	0.80	0.800	1.26	1.008	2.60
JF0888T	5.20	0.52	0.00	0.00	0.000	0.35	0.000	0.65
JF1664C	11.03	1.00	50.00	1.00	1.000	0.36	0.360	1.30
JF1664T	9.74	0.89	43.82	0.88	0.876	0.89	0.780	0.65
MN1510C	15.72	1.00	30.00	1.00	1.000	0.58	0.580	4.55
MN1510T	15.21	0.95	19.40	0.99	0.951	1.50	1.427	0.00
OS0620C	13.02	1.00	2.37	0.19	0.190	1.73	0.329	0.00
OS0620T	0.80	0.08	0.00	0.00	0.000	0.20	0.000	2.60
SN0680C	19.37	1.00	40.00	1.00	1.000	1.32	1.320	0.00
SN0680T	8.73	0.88	29.10	0.97	0.868	1.67	1.450	0.65
SN1099C	22.62	0.90	20.00	1.00	0.869	0.90	0.782	0.00
SN1099T	20.01	0.80	17.68	0.88	0.768	0.95	0.730	0.00
WB0919C	14.99	1.00	27.03	0.68	0.676	3.33	2.251	0.65
WB0919T	11.69	0.89	15.00	0.38	0.375	0.64	0.240	1.95
WB1583C	15.75	1.00	17.96	0.85	0.853	1.13	0.964	0.65
WB1583T	13.44	0.96	23.91	0.86	0.853	2.20	1.877	0.00
WL1840C	21.70	0.91	30.00	1.00	0.915	0.92	0.842	0.65
WL1840T	19.88	0.84	30.88	1.00	0.844	0.34	0.287	0.00
WO0884C	17.22	1.00	30.00	1.00	1.000	3.24	3.240	0.00
WO0884T	12.96	0.85	32.44	0.81	0.811	1.27	1.030	0.65
WO1581C	19.63	1.00	30.00	1.00	1.000	2.50	2.500	0.65
WO1581T	16.78	0.94	24.79	0.87	0.862	1.21	1.043	0.00

* - Variable estimates and model output values are weighted averages based on the areas of cover types found in Table 7. Thus, SI values may not correspond to variable estimates and HSI values may not correspond to the lowest SI value.

[a] - HSI * area.

[b] - birds/ha.

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Craig L. Romary
Signature of Graduate Student

Carl W. Prophet
Signature of Major Advisor

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Craig L. Romary
Signature of Author

4 May, 1990
Date

Evaluation of the Habitat Suitability Index Models for the Black-capped Chickadee and Downy Woodpecker
Title of Thesis

Jackie Talbert
Signature of Graduate Office Staff Member

May 4, 1990
Date Received