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Winter Concentration Areas of White-tailed Deer (Odocoileus virginianus) in Illinois: A Discriminant Analysis

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Winter Concentration Areas of White-tailed Deer

(*Odocoileus viginianus*) in Illinois:

(TITLE)

A Discriminant Analysis

BY

Paul A. Brewer

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

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Winter Concentration Areas of White-tailed Deer (*Odocoileus virginianus*) in Illinois: A Discriminant Analysis

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A Thesis

Presented To

The Department of Zoology

Eastern Illinois University

In Partial Fulfillment

Of The Requirements For The Degree

Master of Science

By

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Abstract

Two discriminant models were derived from 40 variables measured in 12 white-tailed deer (Odocoileus virginianus) winter concentration areas and 12 non-concentration areas in east-central Illinois. The first model correctly classified 100% of these areas based on area of refuge, area of upland hardwoods with <50% crown closure, area of bottomland forest with <50% crown closure, distance of unimproved roads, and total topographic relief. This model was tested on 6 winter concentration areas in west-central Illinois and 6 winter concentration areas in northern Illinois. The first discriminant model correctly classified 91.7% of these areas.

The second model originated from the same set of variables, however the refuge area variable was removed in an attempt to classify winter concentration areas without knowledge of refuge areas. This model correctly classified 91.7% of sites in east-central Illinois, and 75% of the areas in west-central and northern Illinois.

Refuge accounted for nearly 59% of the explained variation between winter concentration areas and non-concentration areas. This component of winter habitat was found in all winter concentration areas examined.

These models offer land managers a statistical method of evaluating winter white-tailed deer habitat based on a low number of measurable variables. Winter habitat is presently adequate in Illinois. Changes in land use and/or harvest regulations may create a greater need to locate, preserve, or establish winter deer habitat.

Dedicated to Mrs. Lula F. Brewer

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Introduction

Early studies of deer concentration areas relied on the proximity of food and cover (Webb 1942) and on general forest cover type to delineate areas used by deer in winter (Christensen 1962). In later years, more detailed analyses were completed which distinguished distinct feeding and sheltering areas used in winter from joint feeding-sheltering areas used during the remaining months (Telfer 1967, Hout 1974). Other recent studies have focused on key habitat characteristics, including microclimate, night and day bedding activity, feeding, escape cover and mobility during the winter months (Ozoga and Gysel 1972, Drolet 1976, Stocker and Gilbert 1977, and Moen 1980).

The occurrence of white-tailed deer (Odocoileus virginianus) concentrations in parts of Illinois has been recognized for some time (Piestch 1954). Piestch (1954) and Zwank (1974) have also documented pronounced seasonal movements of deer to and from traditional wintering areas in Illinois and Missouri respectively. These studies provided information of a descriptive nature but did not include a statistical analysis of winter habitat.

The use of multivariate statistical analysis has recently been applied to the problem of differentiating the characteristics of winter white-tailed deer habitat. In central Ontario, principal component analysis and discriminant function analysis were utilized to determine the effects of lakeside cottage development on winter deer habitat (Armstrong et al. 1983). Weber (1979) used discriminant analysis to classify forested areas in northern New Hampshire, locating four habitat variables to correctly classify 93% of forested areas as winter deer yards and areas not used by deer in winter.

White-tailed deer have made a remarkable recovery in Illinois since their apparent extinction near the turn of the century (Pietsch 1954). Presently, deer numbers continue to grow in many areas of the state (Ill. Department of Conservation, Job Progress Report, Federal Aid Project W-87-R, 30 June 1984), while forested acreages continue to be lost to both agriculture and housing development. Although white-tailed deer are known to utilize standing corn, tall weeds and small brushy areas during most of the year, deer usually rely on forested areas for wintering habitat (Gladfelter 1984). The dispersal of white-tails from winter refuge areas to areas open to hunting has been well documented (Sparrowe and Springer 1970, Hawkins et al. 1971, Zagata 1972, Torgerson and Porath 1977). Deer dispersing from refuges thus serve as a nucleus population to replenish areas of high harvest. As deer numbers increase, forested habitats decrease, and Illinois faces possible changes in harvest regulations (F. Loomis, Ill. Department of Conservation, pers. commun.) identification and description of deer winter concentration areas becomes an important management consideration.

The specific objectives of this study were to:

1) quantify certain vegetative, topographic, and human disturbance features of major deer winter concentration areas in east central Illinois (i.e. more than 10 deer annually).

2) determine how these features differ from similar areas not used extensively by deer in winter.

3) develop a set of predictive equations to determine if an area is suitable as a major winter concentration area.

The work presented in this paper is part of an extensive study dealing with the ecology of white-tailed deer in a highly agricultural region in Illinois. The study is funded through Federal Aid in Wildlife Restoration Project Illinois W-87-R with the Illinois Department of Conservation and the Illinois Natural History Survey cooperating.

Study Area

The primary study area is located in the Grand Prairie Division of east-central Illinois, in the counties of Champaign, Christian, DeWitt, Ford, Macon, Piatt and Vermillion counties (Figure 1). The Grand Prairie is a relatively level, poorly drained plain of glacial drift formed by glaciation during the Wisconsonian stage of Pleistocene glaciation. Major stream valleys and extensive moraines provide the greatest topographical relief. Soils are high in organic content and are relatively young, having formed from a thin to moderately thick layer of glacial drift, loess, or sediments of lake beds (Schwegman et al. 1973). The dominant land use is intensive agriculture, chiefly grain farming. Forests are generally confined to areas unsuitable for farming due to wet or rough conditions and to areas in parks and conservation areas. Forests cover less than 4% of the landscape in this region (Roberts 1982).

A secondary study area was located in Marshall and Putnam counties and another was located in Stephenson and Winnebago counties (Figure 1). Marshall and Putnam counties also lie predominantly in the Grand Prairie Division of Illinois, however both of these counties are bisected by the Illinois River and its broad valley and

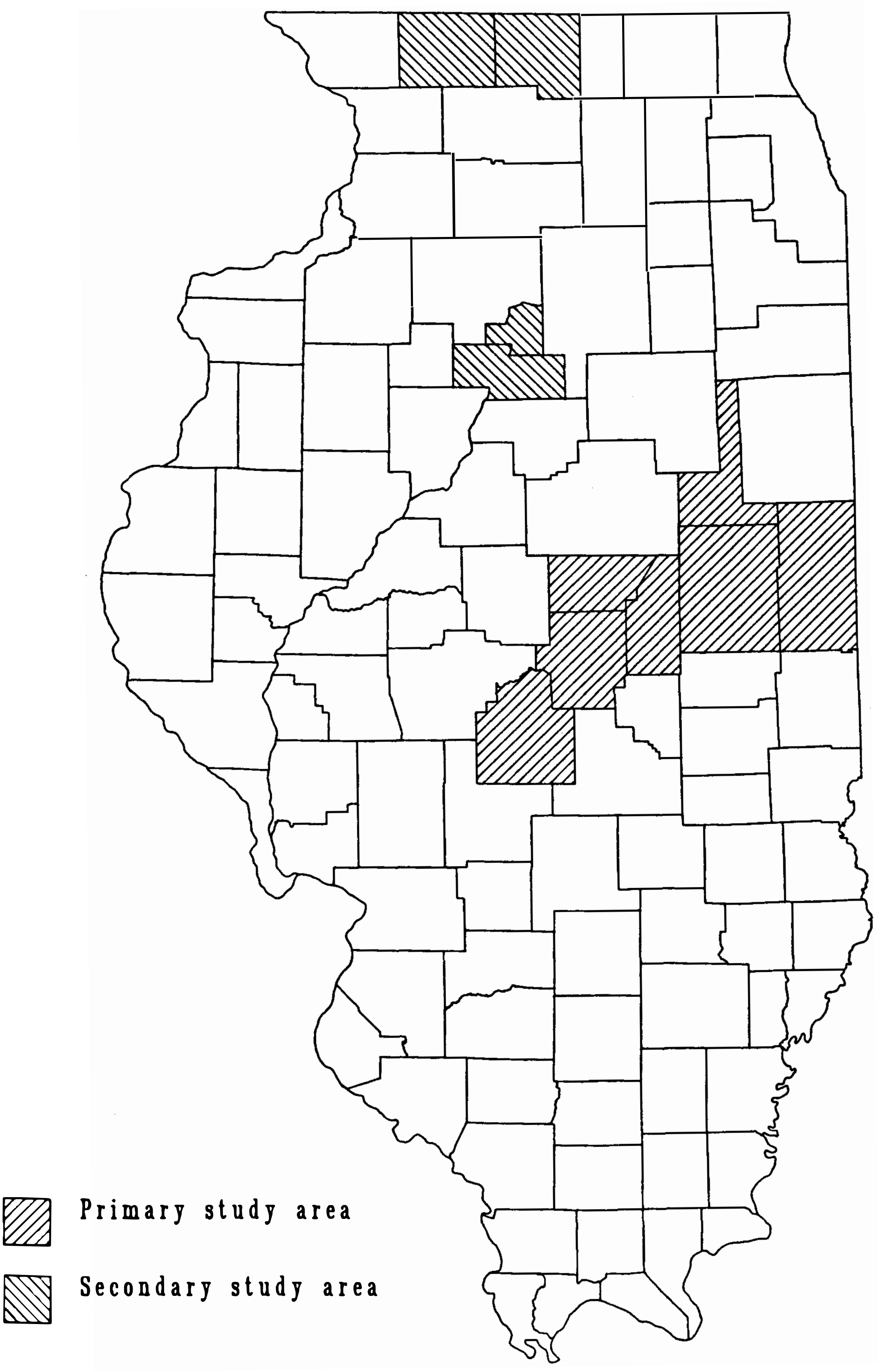

Figure 1. Locations of primary and secondary study areas.

associated bottomland forests. Extensive forests also cover the ridges and bluffs along the river valley and the smaller tributary valleys. Forest coverage is approximately 16% in these two counties (Roberts 1982). Study areas in Winnebago and Stephenson counties lie in the Rock River Hill Country Division of northern Illinois (Schwegman *et al*. 1973). The area is characterized by a rolling topography and a thin mantle of glacial till. Some sections are very rough, with steep bluffs, ridges, and ravines bordering streams. Forest coverage in this area is approximately 5% (Roberts 1982).

Illinois has a continental climate with cold winters and hot, humid summers. Mean January temperatures range from -6^{o} C. to 2^{o} C. from north to south respectively. Mean annual temperatures range from 8^{o} C. to 15^{o} C. from north to south (Schwegman *et al*. 1973).

Methods

Traditional winter concentration areas in both the primary and secondary study areas were located by combining three sources of information:

1. Aerial surveys of all forested tracts in each study area were conducted using a Cessna

172 fixed wing aircraft. Aircraft and pilots were chartered through Darcy Aviation, Inc., a pipeline surveillance firm. All pilots were well trained in slow, low altitude flying techniques. The duration of these surveys was from the winter of 1981-1982 until the winter of 1984-1985. Surveys were conducted over 15.2 cm. (6 inches) or more of snow, with little or no snow clinging to vegetation and snow adequately covering the entire ground. Concentration areas and non-concentration areas in the primary study area of Champaign, Christian, DeWitt, Ford, Piatt, Macon and Vermillion counties were surveyed a minimum of two times. Except for a few hours of one day, these surveys were conducted using the same plane, pilot and observer under similar weather conditions and time of day (Clear, calm - midmorning to midafternoon). Areas in Marshall and Putnam counties were flown once with both a different pilot and observer. Stephenson and Winnebago counties were flown once, using the same observer as in the primary study area with a different pilot.

2. Questionaires and county highway maps

were distributed to Illinois Department of Conservation Police Officers, requesting that they locate traditional concentration areas in their jurisdiction, estimate their populations, and locate the site of greatest population density for each concentration.

3. Telephone and personal interviews were conducted with site superintendents of state and county parks and conservation areas, land managers and district foresters and wildlife biologists to access locations and obtain descriptions of concentration areas.

Radiotelemetry data collected by the Illinois Natural History Survey on the Piatt County Study Area (PCSA) near Monticello, Illinois suggests that a sample area of 10.36 sq. km. (4 square miles) was adequate to incorporate the home ranges of nearly all deer using a winter concentration area in mid-winter. In an earlier portion of this study, Chelsvig (1982) determined that the onset of winter concentration occurred in late December to early January, and that deer dispersed from concentration areas in late April to early May. This area and time factor was used in the sampling of all variables. The sample area was a square, 3.2 kilometers long on each side; all sides were oriented due north to south or due east to west.

In the primary study location, 12 concentration areas were considered in this analysis. Twelve non-concentration areas were also selected on the basis of having apparently adequate cover to support deer in winter, having known summer deer populations, and yet being generally devoid of deer in midwinter. Concentration areas were centered around the location of the largest number of deer observed in that area. Centers of non-concentration areas were located at the center of the best cover available.

In the secondary study locations, 6 concentration areas were surveyed in Marshall and Putnam counties, and 6 concentration areas were surveyed in Stephenson and Winnebago counties.

A total of 40 variables (Table 1) was measured for each of the 36 sample areas. Analysis of land cover was conducted with aerial stereo-photo pairs viewed through a Wild model ST-4 mirror stereoscope. Photointerpretation methods followed those given in Schemnitz (1980) and Avery (1977). The area of each land cover type was computed directly from the aerial photos overlayed on an Apple Graphics Tablet connected to an Apple II+ computer with Graphics Tablet Software. The use of the graphics tablet allowed measurement of the cover types while viewing

Table 1. List of variables used in the analysis of winter concentration areas vs. non-concentration areas.

Variable
Area of refuge
Total forested area
% of sample area forested
Hardwood area classifications:
>50% crown closure
>50% crown closure, upland
>50% crown closure, bottomland
>50% crown closure, upland, >50 years old, wooded
>50% crown closure, upland, >50 years old, pastured
>50% crown closure, upland, <50 years old, wooded
>50% crown closure, upland, <50 years old, pastured
>50% crown closure, bottomland, >50 years old, wooded
>50% crown closure, bottomland, >50 years old, pastured
>50% crown closure, bottomland, <50 years old, wooded
>50% crown closure, bottomland, <50 years old, pastured
<50% crown closure
<50% crown closure, upland
<50% crown closure, bottomland

Table 1. (cont.)

<50% crown closure, upland, >50 years old, wooded

<50% crown closure, upland, >50 years old, pastured

<50% crown closure, upland, <50 years old, wooded

<50% crown closure, upland, <50 years old, pastured

<50% crown closure, bottomland, >50 years old, wooded

<50% crown closure, bottomland, >50 years old, pastured

<50% crown closure, bottomland, <50 years old, wooded

<50% crown closure, bottomland, <50 years old, pastured

Area of shrub-oldfield

Area of cropland

Area of conifers

Area of pasture/grasslands

Number of occupied houses

Linear distance of unimproved roads

Linear distance of light duty roads

Linear distance of secondary highways

Linear distance of primary highways

Linear distance of interstate highways

Number of 3.1 m. (10 ft.) contour lines, NE-SW orientation

Number of 3.1 m. (10 ft.) contour lines, NW-SE orientation

Total topographic relief

Interspersion index

aerial photo pairs with the stereoscope. This technique greatly enhanced the ability to differentiate and measure coverage of vegetation types. In conjunction with the analysis of aerial photographs, most recent USGS topographic maps, county plat books, and field surveys were employed to assess cover types as well as any changes since publication of maps or aerial photos.

The variable "Percent Forest Cover" was determined by dividing the total forest cover measured in each sample area by the total area of each sample area. Area of refuge was determined by measuring forested acreage of designated refuges (ex. Robert Allerton Park) and by measuring other areas of forested refuge determined through landowner interviews in each area. Occupied dwellings were also surveyed at the time of landowner interviews, with the aid of recent USGS topographic maps.

An index of change in topography was calculated by counting the number of 3.1 m. (10 feet) interval contour lines crossed on diagonal lines positioned across the center of each sample area drawn on a USGS topographic map. Total topographic relief within each sample area was also calculated.

An index of interspersion was calculated using a modification of the method described by Baxter and Wolfe (1972). Changes from forest to open cover types were calculated along the same diagonals used to determine topography changes. Number of changes along both diagonals were totaled to arrive at a single index.

Statistical analyses were performed on the CDC Cyber and IBM computer systems at the University of Illinois, using SAS Version 82.3 and BMDP Version 7M discriminant analysis procedures.

Results

The data collected for the 40 variables (Table 1) in the primary study area were first tested to identify variables that were highly correlated. High correlations between independent variables may cause misleading results in discriminant analyses (Cooley and Lohnes 1971). A 40 x 40 correlation matrix for the variables was generated, and highly correlated variables were removed by visual inspection. In deciding which variables should remain, those which were more easily determined were selected, as these variables could be more easily measured by land managers in future applications. This procedure produced 22 orthogonal (non-correlated) variables (Table 2).

The 22 variables shown in Table 2 were than subjected to a canonical discrimination technique using the SAS RSQUARE procedure. This procedure performs all possible

Table 2. List of uncorrelated variables as determined by correlation matrix.

Variable
Area of refuge
Total forested area
Hardwood area classifications:
>50% crown closure
>50% crown closure, upland
>50% crown closure, bottomland
<50% crown closure
<50% crown closure, upland
<50% crown closure, bottomland
Area of shrub-oldfield
Area of cropland
Area of pasture/grasslands
Number of occupied houses
Linear distance of unimproved roads
Linear distance of light duty roads
Linear distance of secondary highways
Linear distance of primary highways
Linear distance of interstate highways

Table 2. (cont.)

Number of 3.1 m. (10 ft.) contour lines, NE-SW orientation

Number of 3.1 m. (10 ft.) contour lines, NW-SE orientation

Total topographic relief

Interspersion index

regressions for one or more dependent variables and a collection of independent variables, and outputs all possible regression models, beginning with the model containing the fewest independent variables and the lowest R^2 value. In this analysis, dummy variables (0 = non-concentration area, 1 = concentration area) were used as the dependent variables. Used in this way, RSQUARE is mathematically equivalent to canonical discrimination (D. Swofford, Ill. Natural History Survey, pers. commun.), with the advantage of allowing inspection of all models considered.

Another result of the RSQUARE procedure revealed that the covariance matrix for data collected on winter concentration areas was nonhomogeneous with the covariance matrix for data collected on non-concentration areas (Chi-square = 76.048, $p < .001$). Heterogeneous covariance matrices severely complicate interpretation of canonical discriminant <u>coefficients</u> (Williams, 1981; my emphasis). However, the canonical technique described above remains an efficient method of reducing a large number of variables to a subset of best discriminating variables (D. Swofford, Ill. Natural History Survey, pers. commun.). Two subsets of 5 variables were chosen using this procedure; 5 variables derived from all 22 orthogonal variables (Table 3), and 5 variables calculated

Table 3. Variables used in discriminant model (Model 1), with the variable "area of refuge" included in the analysis. Positive discriminant effects contributed to classification as a concentration area; negative discriminant effects contributed to classification as a non-concentration area.

Discriminant Variable	Discriminant Effect
hectares of refuge	+
hectares of upland hardwoods, <50% crown closure	-
hectares of bottomland forest <50% crown closure	+
kilometers of unimproved roads	-
total topographic relief	+

Table 4. Variables used in discriminant model (Model 2), with the variable "area of refuge" removed from the analysis. Positive discriminant effects contributed to classification as a concentration area; negative discriminant effects contributed to classification as a non-concentration area.

Discriminant Variable	Discriminant Effect
hectares of upland hardwoods, >50% crown closure	+
hectares of bottomland hardwoods, <50% crown closure	+
hectares of shrub-oldfield	+
hectares of cropland	+
total topographic relief	+

with the variable "area of refuge" removed from the set of orthogonal variables (Table 4).

A more accurate procedure using within-group covariance matrices to compute a classification criterion was used. This procedure, SAS DISCRM, used these within-group matrices to classify areas as winter concentration areas or non-concentration areas based on a measure of generalized squared distance (Rao 1973). Although the DISCRM procedure more accurately classifies areas than does a canonical analysis, a linearized discriminant function is not achievable. The first model (MODEL 1) was derived from variables shown in Table 3, and included the variable measuring area of refuge. The second model (MODEL 2) was constructed from variables shown in Table 4, and did not include the variable refuge.

MODEL 1 classification results for the primary study areas are shown in Table 5. It should be noted that data from these areas were used in the model building process. The model correctly classified 100% of the areas in the primary study region, with probabilities of correct classification for each area at or approaching 100% (Canonical Correlation = .8537, Wilk's Lamda = .2881, F = 8.8954, $p < .0005$).

MODEL 2 classifications for the primary study area are shown in Table 6. This model achieved 91.7% correct classification, also with high probabilities of correct classification for most areas correctly classified (Canonical Correlation = .7605, Wilk's Lamda = .4216, F = 4.9385, p = .005).

Both models were tested on data collected from the secondary study locations in Marshall, Putnam, Stevenson and Winnebago counties. All of these sites were known concentration areas, however the models had no "a priori" knowledge of the classification of these areas during the validation procedure. MODEL 1 provided 91.7% correct classification for the secondary study areas (Table 7), while MODEL 2 correctly classified 75% of these areas (Table 8).

Table 5. Discriminant analysis classification results of the SAS DISCRM model including the variable "area of refuge" for the 24 sample areas in the primary study area.

Area	Classification		Probability of Correct Classification
	From type	Into type	
Champaign/1	CON[a]	CON	1.000
Champaign/2	CON	CON	1.000
Champaign/3	CON	CON	1.000
Champaign/4	CON	CON	0.973
Christian/1	CON	CON	1.000
Christian/2	CON	CON	1.000
DeWitt/2	CON	CON	1.000
Ford/1	CON	CON	0.931
Ford/2	CON	CON	1.000
Macon/1	CON	CON	1.000
Piatt/1	CON	CON	1.000
Piatt/2	CON	CON	1.000
Atwood/NC	NONCON	NONCON[b]	0.999
Camp Creek E./NC	NONCON	NONCON	0.999
Camp Creek W./NC	NONCON	NONCON	0.999

Table 5. (cont.)

Fisher/NC	NONCON	NONCON	0.999
Goose Creek/NC	NONCON	NONCON	1.000
Homer E./NC	NONCON	NONCON	0.998
Homer W./NC	NONCON	NONCON	1.000
Royal/NC	NONCON	NONCON	1.000
Sangamon N./NC	NONCON	NONCON	0.994
Sangamon S./NC	NONCON	NONCON	0.981
Sidney/NC	NONCON	NONCON	1.000
Spring Lake/NC	NONCON	NONCON	1.000

[a] CON - concentration area

[b] NONCON - non-concentration area

Canonical Correlation = .8537

Wilks' Lamda = .2881

$F = 8.8954 \quad p < .0005$

Table 6. Discriminant analysis classification results of the SAS DISCRM model without the variable "area of refuge" for the 24 sample areas in the primary study area.

Area	Classification		Probability of Correct Classification
	From type	Into type	
Champaign/1	CON[a]	CON	1.000
Champaign/2	CON	CON	1.000
Champaign/3	CON	CON	1.000
Champaign/4	CON	CON	0.584
Christian/1	CON	CON	1.000
Christian/2	CON	CON	0.999
DeWitt/2	CON	CON	1.000
Ford/1	CON	NONCON[b]	0.148*
Ford/2	CON	CON	0.661
Macon/1	CON	CON	1.000
Piatt/1	CON	CON	1.000
Piatt/2	CON	NONCON	0.021*
Atwood/NC	NONCON	NONCON	1.000
Camp Creek E./NC	NONCON	NONCON	0.998
Camp Creek W./NC	NONCON	NONCON	0.997

Table 6. (cont.)

Fisher/NC	NONCON	NONCON	0.987
Goose Creek/NC	NONCON	NONCON	0.989
Homer E./NC	NONCON	NONCON	0.995
Homer W./NC	NONCON	NONCON	0.999
Royal/NC	NONCON	NONCON	1.000
Sangamon N./NC	NONCON	NONCON	0.999
Sangamon S./NC	NONCON	NONCON	0.997
Sidney/NC	NONCON	NONCON	0.999
Spring Lake/NC	NONCON	NONCON	0.999

[a] CON - concentration area

[b] NONCON - non-concentration area

* - misclassified observation

Canonical Correlation = .7605

Wilks' Lamda = .4216

$F = 4.9385$ $p < .005$

Table 7. Discriminant analysis classification results testing the SAS DISCRM model derived from the 24 sample areas in the primary study area on data collected in the 12 concentration areas in the secondary study area, with variable "area of refuge" included.

Area	Classification	Probability of Correct Classification
Marshall/1	CON[a]	1.000
Marshall/2	CON	1.000
Marshall/3	CON	1.000
Putnam/1	CON	1.000
Putnam/2	NONCON[b]	0.000*
Putnam/3	CON	1.000
Stephenson/1	CON	1.000
Stephenson/2	CON	1.000
Winnebago/1	CON	1.000
Winnebago/2	CON	1.000
Winnebago/3	CON	1.000
Winnebago/4	CON	1.000

Table 7. (cont.)

[a] CON - concentration area

[b] NONCON - non-concentration area

* - observation misclassified by model

Canonical Correlation = .8537

Wilks' Lamda = .2881

$F = 8.8954 \quad p < .0005$

Table 8. Discriminant analysis classification results testing the SAS DISCRM model derived from the 24 sample areas in the primary study area on data collected in the 12 concentration areas in the secondary study area, without variable "area of refuge" .

Area	Classification	Probability of Correct Classification
Marshall/1	NONCON[a]	0.071*
Marshall/2	CON[b]	1.000
Marshall/3	CON	1.000
Putnam/1	CON	1.000
Putnam/2	NONCON	0.000*
Putnam/3	CON	1.000
Stephenson/1	NONCON	0.000*
Stephenson/2	CON	1.000
Winnebago/1	CON	1.000
Winnebago/2	CON	1.000
Winnebago/3	CON	1.000
Winnebago/4	CON	1.000

Table 8. (cont.)

[a] NONCON - non-concentration area

[b] CON - concentration area

* - observation misclassified by model

Canonical Correlation = .7605

Wilks' Lamda = .4216

$F = 4.9385$ $p < .005$

Discussion

Model 1

The first discriminant model used the variables area of refuge, area of upland hardwoods with >50% crown closure, area of bottomland forest with <50% crown closure, distance of unimproved roads, and total topographic relief to correctly classify 100% of study sites in the primary study area as winter concentration areas or non-concentration areas. This model correctly classified 91.7% of study sites in the secondary study area.

The importance of refuge in white-tailed deer management in the Midwest agricultural region is receiving increasing attention (Gladfelter 1984). In this region of Illinois, refuge accounted for nearly 59% of the explained variation between winter concentration areas and non-concentration areas. Information collected during the Illinois Natural History Survey's study has shown that deer move to areas, especially to bed, where human disturbance is minimal. Deer in the Piatt County Study Area have also been shown to move into refuge areas during the shotgun portion of the Illinois deer hunting season (Ill. Department of Conservation, Job Progress Report, Federal Aid Project W-87-R, 23 September 1983). Some refuge was present on all white-tailed deer winter concentration areas examined during this study, demonstrating the importance of this component of winter habitat in the region.

Upland hardwoods with <50% crown closure negatively effected classification as a winter concentration area. Verme (1965), Ozoga (1968), and Weber (1981) all reported that high softwood crown closure was positively correlated with decreased wind speed, decreased snow depth, increased average winter temperature, increased relative humidity, and decreased daily temperature fluctuation. Although these effects are less pronounced, high crown closure hardwoods have similar effects (Robinette 1972). However, bottomland forest with <50% crown closure was found to be positively associated with winter concetration areas. These results are in agreement with those found by Weber (1981) and Aldous (1941). Although areas with high crown closure act to reduce radiative heat losses and wind chill, open areas may allow deer to benefit from radiant solar energy. A mixture of both closed and open areas would allow deer to benefit from both thermal regimes.

The presence of unimproved roads negatively influenced selection of a site as a wintering area. Access drives to farmsteads, and access roads to centers of otherwise inaccessable sections, are often classified as unimproved roads on United States Geological Survey topographic maps. I view the presence of these roads as an index of human activity. Frequently, these roads are associated with farmsteads that are located well into the interior of typical 2.59 sq. km. (1 sq. mi.) sections found in the agricultural region of Illinois. Findings of other studies have shown no home range shifts due to hunting (Autry 1967), harassment by dogs (Sweeney et al. 1971) or intensive ranching (Hood and Inglis 1974). It is important to note that each of these studies were conducted in different environments than that which occurs in the northern two-thirds of Illinois. Autry (1967) conducted his research in heavily forested southern Illinois, Sweeney et al. (1971) worked in a variety of habitats, all well forested, while Hood and Inglis (1974) worked in southern Texas with "abundant hiding cover" available. In all of these studies, does and fawns demonstrated greater home range fidelity, often circling back to return to a home range, than did adult males, which frequently left their home range in a long distance run to return at a later time. In small woodlots or narrow linear forests along streams typical of east central Illinois, such escape patterns often lead to extended time in relatively open habitat, and may lead to selection of areas where disturbances are minimized. This view is supported by work in Missouri by Progulske and Baskett (1958), who stated that disturbance by hounds caused white-tailed deer to move long distances, often leaving their established home range.

The positive effect of change in topography, particularly steep slopes, is well documented (Telfer 1978, Huot 1974, Strong 1977, Webb 1948). Ravines and hollows in areas of high topographic relief offer protection from the wind. Southwest facing slopes provide a more normal solar angle which increases the effects of insolation (Ozoga and Gysel 1972).

Model 2

The second model (MODEL 2) was used as a method of evaluating habitat and human disturbance variables if the refuge status of an area is unknown. It is important to understand that the variable "area of refuge" was removed in an experimental attempt to classify areas without knowledge of refuge, however refuge did occur on all winter concentration areas. This model correctly classified 91.7% of the primary study sites and 75% of the secondary study areas.

The importance of a mix of vegetation was again indicated by this model. Variables in this "habitat model" that did not enter MODEL 1 were area of upland hardwoods with >50% crown closure, area of shrub-oldfield, and area of cropland. The upland hardwood variable is essentially the inverse of the upland hardwood variable in MODEL 1, and its effect in the classification is also the inverse, being positive in the classification (i.e. the importance of high crown closure in part of the wintering habitat is also indicated). The value of early successional habitat for white-tailed deer has long been heralded (Schemnitz 1980, Halls 1984). Shrub-oldfield habitats provide not only thermal and escape cover, but also provide a wide variety of foods utilized by white-tailed deer (Harlow 1984).

The positive association of area of cropland to winter concentration is counter-intuitive. However, it is important to note that these models are based on a combination of variables that are important in the classification of winter habitat. Agricultural crops, particularly corn (*Zea mays*) and soybeans (*Glycine max*), make up the major portion of the diet of white-tailed deer in the Midwest (Korshgen 1962, Mustard and Wright 1964, Watt *et al*. 1967, Nixon *et al*. 1970). Particularly in winter, when high energy food sources are most needed, cropland may be an important part of winter habitat given the availablity of forested cover types.

Both statistical models indicate the importance of the following factors in a white-tailed deer winter concentration area:

1. Thermal cover - to minimize fluctuations in temperature, wind speed, and relative humidity, and to increase opportunity for insolation.

2. Adequate high energy foods from croplands, as well as a broad mixture of foods from early successional and open canopy habitats.

3. Reduction in disturbance - deer select winter habitats where refuge is present, and where disturbance associated with humans is minimized. Although deer can tolerate human disturbance (ex. urban deer herds in Chicago), a preference is shown for sites where this factor is lessened.

Misclassifications

MODEL 1 correctly classified 100% of winter concentration and non-concentration areas in the primary study area, but misclassified 1 of 12 sites in the secondary, or test area. This winter concentration area, Putnam/2, was classified as a non-concentration area. Examination of the variables did not reveal an obvious reason for this misclassifcation.

MODEL 2 correctly classified 22 of 24 areas in the primary study area. the 2 misclassifications, Piatt/2 and Ford/1, were both winter concentration areas misclassified as non-concentration areas. Piatt/2 has as it core Lodge Park Forest Preserve, just north of Monticello, Illinois. Winter feeding of deer in and around this park by adjacent landowners, and in some years by park personnel, may contribute to its use as a winter concentration area. This park has large areas of mature, closed canopy, bottomland forest, a habitat characteristic not found to be an important difference between winter concentration areas and non-concentrations areas. Mature bottomland forests are infrequently used by deer in winter on the Illinois Natural History Survey's Piatt County Study Area. Ford/1 is a small group of isolated woodlots along the Big 4 drainage ditch near Paxton, Illinois. Although this site is not heavily forested, these woodlots are essentially isolated by many miles of barren crop fields in winter. Winter feeding may also play a role in this area. Approximately 8.1 ha. (20 acres) of unharvested corn have been noted each year an aerial survey was conducted. The owner of this field cited both an interest in feeding deer and field access problems as reasons for leaving the standing corn on a continual basis.

Three of the 12 secondary, or test areas were misclassified by MODEL 2. These were Marshall/1, Putnam/2, and Stephenson/2; all winter concentration areas misclassified as non-concentration areas. Marshall/1 was unusual only in that it was somewhat small (94 forested hectares) and had a large number of unimproved roads. I found no obvious reason for the misclassification of Putnam/2, as was the case for this misclassification in MODEL 1. Stephenson/2, located near Cedarville, Illinois, could possibly be another case of the influence of winter feeding; during the aerial survey of this area, 18 deer were sighted feeding in a field of partially standing corn. Landowner interviews did not reveal that this was a common practice; however, deer have traditionally wintered in this area.

These misclassifications demonstrate a weakness in the models; they are not sensitive to unusual situations of winter concentration. In all cases of misclassification, winter concentration areas were incorrectly classified as non-concentration areas. This is due in part to the sampling of only concentration areas in the secondary study area. However, this type of misclassification was also the only type to occur in the primary area. Winter feeding is generally not a predictable and constant practice; however, in some areas supplemental feeding may influence resident populations of deer to remain at a site rather than move to other areas with more suitable habitat. Other factors, such as unusual harassment, social grouping, poaching, etc. were not considered in these models because of the difficulty in detecting and measuring these variables. The effect of these variables on winter habitat selection is unknown.

Management Implications

These models provide a numerical analysis of winter white-tailed deer habitat in the northern two-thirds of Illinois. By using these models, land managers may evaluate the capability of an area to support deer in winter. MODEL 2, which is not dependent on the measurement of area of refuge, could be used to access site suitability for refuge establishment, habitat modification, or to make adjustments in land use planning.

The results of this study underline deer usage of refuges in winter. The establishment and maintenance of refuges may have other management implications. Gladfelter (1978) and Chelsvig (1982) have both suggested that refuges are useful in providing a source of colonizing individuals in areas where harvest reduces or eliminates local deer populations. Currently, increasing population trends of deer in Illinois indicate that winter habitat, including areas of refuge, are adequate. In some areas, refuge may create problems of crop depredation, increased deer/vehicle accidents, and habitat depletion. Future changes in harvest regulations and/or land use may amplify the need to locate, preserve, or establish winter habitat for white-tailed deer.

LITERATURE CITED

Aldous, S. E. 1941. Deer management suggestions for northern white cedar types. J. Wildl. Manage. 5: 90-94.

Armstrong, E., D. Euler and G. Racey. 1983. White-tailed deer and cottage development in central Ontario. J. Wildl. Manage. 47:605-612.

Avery, T. E. 1977. Interpretation of aerial photographs. 3rd ed. Burgess Publ. Co. Minneapolis, Minn. 392 pp.

Autry, D. C. 1967. Movements of white-tailed deer in response to hunting on Crab Orchard National Wildlife Refuge. M.S. Thesis. Southern Illinois University, Carbondale. 42 pp.

Baxter, W. L., and C. W. Wolfe. 1972. The interspersion index as a technique for evaluation of bobwhite quail habitat. Proc. First Nat. Bobwhite Quail Symp. 1: 158-165.

Chelsvig, J. E. 1982. Seasonal movements of white-tailed deer in east-central Illinois. M. S. Thesis. Eastern Illinois University, Charleston. 51 pp.

Christensen, E. M. 1962. Classification of the winter habitat of the white-tailed deer in northern Wisconsin based on forest ordination. Ecology 43: 134-135.

Cooley, W. W., and P. R. Lohnes. 1971. Multivariate data analysis. John Wiley and Sons, New York, N.Y. 364 pp.

Drolet, C. A. 1976. Distribution and movements of white-tailed deer in southern New Brunswick Canada in relation to environmental factors. Can. Field Nat. 90:123-136.

Gladfelter, H. L. 1984. Midwest agricultural region. Pages 427-440 in L. K. Halls ed. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pa. and The Wildlife Management Institute, Washington, D. C. 870 pp.

Halls, L. K. ed. 1984. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pa. and The Wildlife Management Institute, Washington, D. C. 870 pp.

Harlow, R. F. 1984. Habitat evaluation. Pages 601-628 in L. K. Halls ed. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pa. and The Wildlife Management Institute, Washington D.C. 870 pp.

Hawkins, R. E., W. D. Klimstra, and D. C. Autry. 1971. Dispersal of deer from Crab Orchard National Wildlife Refuge. J. Wildl. Manage. 35:216-220.

Hood, R. E., and J. M. Inglis. 1974. Behavioral responses of white-tailed deer to intensive ranching operations. J. Wildl. Manage. 38:488-498.

Huot, J. 1974. Winter habitat of white-tailed deer at Thirty-one Mile Lake Quebec. Can. Field Nat. 88:293-301.

Korschgen, L. J. 1962. Foods of Missouri deer, with some management implications. J. Wildl. Manage. 26:164-172.

Moen, A.N. 1980. The biology and management of wild ruminants. Cornerbrook Press, Lansing, N.Y. 7 vol. (unnumbered pages).

Mustard, E. W., and V. Wright. 1964. Food habits of Iowa deer. P-R Proj. W-99-R-3. Iowa Conservation Commission, Des Moines. 35 pp.

Nixon, C. M., M. W. McClain, and K. R. Russell. 1970. Deer food habits and range characteristics in Ohio. J. Wildl. Manage. 34:870-886.

Ozoga, J. J. 1968. Variations in the microclimate in a conifer swamp deer yard in northern Michigan. J. Wildl. Manage. 32:574-585.

Ozoga, J. J., and L. W. Gysel. 1972. Response of white-tailed deer to winter weather. J. Wildl. Manage. 36:892-896.

Pietsch, L. R. 1954. White-tailed deer populations in Illinois. Biol. Notes 34. Illinois Natural History Survey Division, Champaign. 22 pp.

Progulske, D. R., and T. S. Baskett. 1958. Mobility of Missouri deer and their harassment by dogs. J. Wildl. Manage. 22:184-192.

Rao, C. R. 1973. Linear statistical inference and its applications. John Wiley and Sons, New York, N.Y. 310 pp.

Roberts, P. 1982. Forests of Illinois. Illinois Department of Conservation, Springfield. Map.

Robinette, G. O. 1972. Plants/people/and environmental quality. U.S. Department of the Interior, National Park Service, Washington, D.C. 138 pp.

Schwegman, J., G. B. Fell, M. D. Hutchinson, G. Paulson and J. White. 1973. Comprehensive plan for the Illinois Nature Preserves Commission. Part 2. The natural divisions of Illinois. Nature Preserves Commission, Rockford, Ill. 32 pp.

Schemnitz, S. D. ed. 1980. Wildlife management techniques manual. The Wildlife Society, Washington, D.C. 686 pp.

Sparrowe, R. D., and P. F. Springer. 1970. Seasonal activity patterns of white-tailed deer in eastern South Dakota. J. Wildl. Manage. 34:420-431.

Strong, K. F. 1977. Evaluative review of deer yard management in New Hampshire and Maine. N. H. Fish and Game Dept., Concord, N. H.

Sweeney, J. R., R. L. Marchinton, and J. M. Sweeney. 1971. Responses of radio-monitored white-tailed deer chased by hunting dogs. J. Wildl. Manage. 35:707-716.

Telfer, E. S. 1967. Comparison of a deer yard and a moose yard in Nova Scotia. Can. J. Zool. 45:485-490.

____________. 1978. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42:352-361.

Torgerson, O., and W. Porath. 1977. Impact of river-bottom habitat, refuges, and hunting deer populations in the Lower Grand River Valley. P-R Proj. W-13-R-30. Missouri Department of Conservation, Jefferson City. 32 pp.

Verme, L. J. 1965. Swamp conifer deer yards in northern Michigan. Their ecology and management. J. Forestry. 63:523-529.

Watt, P. G., G. L. Miller, and R. J. Robel. 1967. Food habits of white-tailed deer in northeastern Kansas. Trans. Kansas Acad. Sci. 70:223-240.

Webb, W. L. 1942. A method for wildlife management mapping in forested areas. J. Wildl. Manage. 6:38-43.

__________. 1948. Environmental analysis of a winter deer range. Trans. N. Amer. Wildl. Conf. 13:442-449.

Weber, S. J. 1981. A quantitative analysis of white-tailed deer winter concentration areas in northern New Hampshire. M. S. Thesis. University of New Hampshire, Concord. 68pp.

Williams, B. K. 1981. Discriminant analysis in wildlife research: theory and applications. Pages 59-71 in D. E. Capen ed. The use of multivariate statistics in studies of wildlife habitat. General Technical Report RM-87. Rocky Mountain Forest Experiment Station, Fort Collins, Colo. 249 pp.

Zagata, M. D. 1972. Range and movement of Iowa deer in relation to Pilot Knob State Park, Iowa. Ph. D. Thesis. Iowa State University, Ames. 249 pp.

Zwank, P. 1974. Refuges as populations centers for deer in threatened habitat. M.S. Thesis. University of Missouri, Columbia. 70 pp.

Appendix A

Deer management regions, county name/concentration area number, topographic quadrangle and ownership of white-tailed deer winter concentration areas included in this study. Public area names are given for public areas (SP = state park, FP = county forest preserve, CA = conservation area, IDOC = Illinois Department of Conservation).

Region	County/CA#	Topo. Quad	Private/Public
1	Stephenson/1	Lena 7.5'	Lake Le-Aqua-Na SP
1	Stephenson/2	Dakota, Lena, Freeport East, Freeport West, 7.5'	Private
1	Winnebago/1	Winnebago 7.5'	Severson Dells FP
1	Winnebago/2	Pecatonica 7.5'	Pecatonica FP
1	Winnebago/3	Rockford North, Caledonia 7.5'	Rock Cut SP
1	Winnebago/4	Shirland 7.5'	Sugar River FP
2	Ford/1	Perdueville 7.5'	Private
2	Ford/2	Buckley NW 7.5'	Private
3	Marshall/1	La Rose 7.5'	Private

Appendix A (cont.)

3	Marshall/2	Rome 7.5'	Marshall Co. CA
3	Marshall/3	Wenona, Varna 7.5'	Private
3	Putnam/1	Putnam 7.5'	Private
3	Putnam/2	Florid, DePue 7.5'	Private
3	Putnam/3	McNabb 7.5'	Private
5	Champaign/1	Mahomet 7.5'	Private
5	Champaign/2	St. Joseph, Homer 7.5'	Salt Fork FP
5	Champaign/3	Penfield 7.5'	Middle Fork FP
5	Champaign/4	Urbana, Thomasboro 7.5'	University of Illinois, Natural Area
5	Christian/1	Edinburg 7.5'	Lake Sangchris SP
5	Christian/2	Taylorville 7.5'	Private
5	DeWitt/2	DeWitt 7.5'	Illinois Power Co., IDOC
5	Macon/1	Argenta 7.5'	Private
5	Piatt/1	Monticello, Weldon East, Cerro Gordo 7.5'	Allerton Park University of Illinois Natural Area

Appendix A (cont.)

5	Piatt/2	Monticello 7.5'	Lodge Park FP
5	Piatt/3	Seymour, Mahomet 7.5'	Private

Appendix B

Deer management regions, county name/concentration area number, township(s) location, and concentration area (CA) center of white tailed deer winter concentration areas included in this study.

Region	County/CA#	Township(s)	Center of CA
1	Stephenson/1	West Point	SW1/4, S17, T28N, R6E
1	Stephenson/2	Buckeye	NW1/4, S31, T28N, R8E
1	Winnebago/1	Winnebago	SW1/4, S36, T26N, R11E
1	Winnebago/2	Pecatonica	SE1/4, S10, T27N, R10E
1	Winnebago/3	Harlem	SW1/4, S27, T45N, R2E
1	Winnebago/4	Shirland	NW1/4, S4, T28N, R11E
2	Ford/1	Patton	SE1/4, S10, T23N, R9E
2	Ford/2	Brenton	SE1/4, S31, T26N, R9E
3	Marshall/1	Bell Plain	NE1/4, S27, T29N, R1W
3	Marshall/2	Lacon Richland	NW1/4, S24, T29N, R2W
3	Marshall/3	Roberts	NW1/4, S8, T30N, R1W

Appendix B (cont.)

3	Putnam/1	Senachwine	SW1/4, S13, T14N, R9E
3	Putnam/2	Hennepin	SE1/4, S11, T32N, R2W
3	Putnam/3	Magnolia	NE1/4, S21, T31N, R1W
5	Champaign/1	Mahomet	NW1/4, S2, T20N, R7E
5	Champaign/2	Ogden South Homer	SW1/4, S31, T19N, R14W
5	Champaign/3	Kerr	NW1/4, S8, T22N, R14W
5	Champaign/4	Urbana	SW1/4, S1, T19N, R9E
5	Christian/1	South Fork	NW1/4, S30, T13N, R4W
5	Christian/2	Johnson	SE1/4, S4, T12N, R2W
5	DeWitt/2	Harp	SW1/4, S34, T20N, R3E
5	Macon/1	Whitmore	NW1/4, S17, T17N, R4E
5	Piatt/1	Monticello Willow Branch	SE1/4, S21, T18N, R5E
5	Piatt/2	Sangamon	NE1/4, S31, T19N, R6E
5	Piatt/3	Sangamon	NE1/4, S12, T19N, R6E

Appendix C

LITERATURE REVIEW

Studies of winter concentration of white-tailed deer (Odocoileus virginianus) have been conducted for a long period of time. The majority of these studies concern areas at greater latitudes than Illinois. This review will follow an historical perspective, beginning with early winter concentration area research and progressing to recent studies.

Northern Coniferous Region

Holsey and Ziebarth (1935), found that deer concentrated on south and southeast slopes of white pine (Pinus strobis), eastern hemlock (Tsuga canadensis) and an assortment of hardwood forest types during a severe winter in north central Massachusetts.

Cook and Hamilton (1942) described areas of the Allegheny plateau of central New York which were used as winter concentration areas of white-tailed deer. They found that these areas were comprised of softwood swamps and/or south slopes.

In New York, forest types used most frequently by wintering white-tailed deer were spruce flats and spruce swamps, with red spruce (Picea rubens), balsam fir (Abies balsamea) and eastern hemlock providing the bulk of the cover (Webb 1948). During a previous study, Webb (1942) developed a species rating system for quantifying food supplies and properties of forest cover. He concluded that cover is the most important factor in determining winter concentration areas. Webb (1948) also discovered that either steep slopes or level areas of land positively influenced winter concentration area selection, while moderately sloping areas were shown to negatively influence concentration.

Optimum winter concentration areas of northern Michigan were large, even-ageded stands dominated by northern white cedar (Thuja occidentalis) with balsam fir, black spruce (Picea mariana), and tamarack (Larix laricina) being important associates (Verme 1965). Black ash (Fraxinus nigra), red maple (Acer rubrum), balsam poplar (Populus balsamifera), and paper birch (Betula paperifera) were intermixed with these associates. Common shrubs in the Michigan areas were speckled alder (Alnus rugosa) and red osier dogwood (Cornus stolonifera).

In Nova Scotia, Telfer (1967), learned that a deer winter concentration area was comprised of a continuous stand of red spruce and balsam fir on a southwest facing slope. He also noted that the deer winter concentration area was 152.4 m. (500 feet) lower in elevation than a nearby moose (*Alces alces*) yard.

Rongstad and Tester (1969) reported that white-tailed deer in northern Minnesota used winter concentrations areas similar to those described by Ozoga (1968) in northern Michigan. These winter concentration areas, comprised mostly of northern white cedar with black spruce, tamarack, speckled alder, winterberry (*Ilex verticillata*) and willow (*Salix* spp.) also present, occured in three distinct even-aged stands consisting of (1) mature timber 12.7-27.9 cm. (5-11 inches) diameter at breast height (DBH), (2) pole-size trees 7.6-17.8 cm. (3-7 inches) DBH, and (3) small saplings 2.5-7.6 cm. (1-3 inches) DBH. Wetzel *et al*. (1975) found that other white-tailed deer winter concentration areas were comprised of four forest types; jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), black spruce, and northern white cedar.

In New Brunswick, Telfer (1970) found that white-tailed deer concentrated in dense conifer and mixed hardwood stands when the mean snow depth reached 38 cm. in more open areas of hardwood stands. Drolet (1976), also in New Brunswick, reported that white-tailed deer preferred a dense mixed forest in winter, beginning to concentrate when snow accumulated to 30 cm. or more in hardwood stands. Deer dispersed from wintering areas after the temperature was above 5.5^{o} C. for several days.

Alberta white-tails did not concentrate during a snowless winter, but did move to concentration areas the next winter with the arrival of early snows (Kramer 1970).

Ozoga and Gysel (1972) described a wintering area in northern lower Michigan as a mixture of northern white cedar and balsam fir in the 10.2-20.3 cm. (4-8 inch) DBH size class, with white pine of 20.3-48.3 cm. (8-19 inches) DBH occurring on some ridges and knolls. Understory species included red maple, black ash, red osier dogwood, winterberry, willow and wild raisin (Viburnum cassinoides).

In Quebec, intolerant mixed woods species and conifer-intolerant hardwoods appeared to be the more important cover associations when both browse production and deer occupancy were considered (Huot 1974). White spruce Picea glauca), balsam fir, and eastern hemlock were selected as shelter trees. In January, deer occupied stands where 85% of the basal area and 93% of the tree volume were coniferous. Huot also found that deer most often bedded on southwest facing slopes in February, and that even though the shelter quality and food availability were similar for each area, deer moved to areas of low altitude after January.

New Hampshire deer concentration areas were stands containing mature softwood trees with a minimum DBH of 12.7 cm. (6 inches) (Strong 1977). Prime concentration areas had trees over 25.4 cm (10 inches) DBH. Balsam fir, red spruce, and eastern hemlock were the most important shelter species. Strong also found that that best winter shelter was found below 609.6 m. (2000 feet) elevation, and that steep slopes in any winter concentration area often provided reduced snow depths independent of the softwood canopy influence.

In Alberta, Telfer (1978) found that browse availability had little or no effect on selection of winter concentration areas by white-tailed deer. Steep south facing slopes and mature spruce-fir stands made up most of the winter concentration areas.

Euler and Thurston (1980) summarized characteristics of hemlock stands used by wintering white-tailed deer in Ontario. They used a multiple regression analysis to determine that percent softwood crown closure, the number of stems of food species per hectare, and the percent of basal area comprised of balsam fir were all significantly greater for areas of high winter deer use versus areas picked at random throughout large softwood stands. However, the maximum amount of variation explained by these parameters was 26%.

Weber (1981) used discriminant analysis techniques to derive 4 predictive equations to determine habitat suitability for white-tailed deer winter concentration areas in New Hampshire. Weber achieved 95% classification accuracy with a 5 variable equation using a combination of site index, area of stand, basal area, softwood crown closure, and change in elevation within each stand.

Similarly, Armstrong et al. (1983) used discriminant analysis techniques to classify winter deer habitat in area of cottage development in central Ontario. They found that 4 functional habitat types; travel lanes, night-bedding areas, day-bedding areas and feeding sites, were separated on the basis of canopy closure, coniferous and deciduous browse units, vegetation volume, and numbers of dead branches. Cottage development in areas used by deer was found to reduce the quality of winter habitat.

Midwest and Southern Hardwood Region

In more southern areas, including southern Michigan (Jenkins and Bartlett, 1959), southeastern Ohio (Chapman, 1939), and Pennsylvania (Gerstell, 1938) white-tailed deer seem to concentrate for lesser periods of time, and concentration appears to be more dependent of severe weather conditions. In Missouri, Progulske and Baskett

(1958) found that winter ranges of individual deer tended to be larger than summer ranges. Severinghaus and Cheatum (1956) concluded that in areas with little seasonal change in weather, deer remain in one area throughout the year. Bridges and Marchinton (1969) found no seasonal shifts in range by white-tailed deer in Florida.

Summary

This literature review revealed the following major points concerning white-tailed deer winter concentrations:

1. Winter concentration research has been most commonly done in northern coniferous forests, where winter concentration tends to be both of long duration and confined to a small area.

2. Research has primarily focused on species composition and forest size classes, with a wide range of conclusions.

3. Cover, rather than food supply, appears to be the key element in selection of wintering sites.

4. As latitude decreases, there is a corresponding decrease both in duration of winter concentration and extent to which concentration occurs.

5. Multivariate analyses have only recently been used in the evaluation of winter white-tailed deer habitat. A

review of current literature revealed only 2 studies which used discriminant analysis techniques for habitat classification.

LITERATURE CITED

Armstrong, E., D. Euler and G. Racey. 1983. White-tailed deer and cottage development in central Ontario. J. Wildl. Manage. 47:605-612.

Bridges, R. J., and R. L. Marchinton. 1969. Winter and spring movement of individual white-tailed deer on Eglin Reservation, Florida. Bull. Ga. Acad. Sci. 27(2):83.

Chapman, F. B. 1939. The whitetail deer and its management in southeastern Ohio. Trans. N. Am. Wildl. Conf. 4:257-267.

Cook, D. B., and W. J. Hamilton, Jr. 1942. Winter habits of white-tailed deer in central New York. J. Wildl. Manage. 6:287-291.

Drolet, C. A. 1976. Distribution and movements of white-tailed deer in southern New Brunswick Canada in relation to environmental factors. Can. Field Nat. 90(2):123-136.

Euler, D., and L. Thurston. 1980. Characteristics of hemlock stands related to deer use in east-central Ontario. J. Appl. Ecol. 17:1-6.

Gerstell, R. 1938. The Pennsylvania deer problem in 1938. Pennsylvania Game News. 9(5):12-13, 31; 9(6):10-11, 27, 32; 9(7):6-7, 29.

Holsey, N. W., and R. K. Ziebarth. 1935. Some winter relations of the white-tailed deer to the forests in north central Massachusetts. Ecology. 26:535-553.

Huot, J. 1974. Winter habitat of white-tailed deer at Thirty-one Mile Lake Quebec. Can. Field Nat. 88:293-301.

Jenkins, D. H., and I. H. Bartlett. 1959. Michigan white-tails. Michigan Dept. of Cons., Lansing, Mich. 80 pp.

Kramer, A. 1970. Notes on the winter ecology of the mule and white-tailed deer in the Cypress Hills, Alberta, Canada. Can. Field Nat. 85:141-145.

Ozoga, J. J. 1968. Variations in the microclimate in a conifer swamp deer yard in northern Michigan. J. Wildl. Manage. 32:574-585.

Ozoga, J. J., and L. W. Gysel. 1972. Response of white-tailed deer to winter weather. J. Wildl. Manage. 36:892-896.

Progulske, D. R., and T. S. Baskett. 1958. Mobility of Missouri deer and their harassment by dogs. J. Wildl. Manage. 22:184-192.

Rongstad, O. J., and J. R. Tester. 1969. Movements and habitat use of white-tailed deer in Minnesota. J. Wildl. Manage. 33:366-379.

Severinghaus, C. W., and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 in W. P. Taylor ed. The deer of North America. The Stackpole Co., Harrisburg, Pa. and The Wildlife Management Institute, Washington, D. C. 668 pp.

Strong, K. F. 1977. Evaluative review of deer yard management in New Hampshire and Maine. N. H. Fish and Game Dept., Concord, N. H.

Telfer, E. S. 1967. Comparison of a deer yard and a moose yard in Nova Scotia. Can. J. Zool. 45:485-490.

____________. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Manage. 34:553-559.

____________. 1978. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42:352-361.

Verme, L. J. 1965. Swamp conifer deer yards in northern Michigan. Their ecology and management. J. Forestry. 63:523-529.

Webb, W. L. 1942. A method for wildlife management mapping in forested areas. J. Wildl. Manage. 6:38-43.

__________. 1948. Environmental analysis of a winter deer range. Trans. N. Amer. Wildl. Conf. 13:442-449.

Weber, S. J. 1981. A quantitative analysis of white-tailed deer winter concentration areas in northern New Hampshire. M. S. Thesis, Univ. of N. H. 68 pp.

Wetzel, J. F., J. R. Waumbaugh, and J. M. Peek. 1975. Appraisal of white-tailed deer winter habitats in northeastern Minnesota. J. Wildl. Manage. 34:56-66.