HABITAT REQUIREMENTS OF WHITE-TAILED DEER IN THE POST OAK-BLACKJACK OAK HABITAT TYPE

By

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Bachelor of Science

Arizona State University

Tempe, Arizona

1977

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1980

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IN THE POST OAK-BLACKJACK OAK

HABITAT TYPE

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PREFACE

The purpose of this study was to evaluate habitat requirements of white-tailed deer in the post oak-blackjack oak habitat type of Oklahoma. Information on habitat use patterns, factors affecting the patterns, activity levels, home range characteristics, centers of activity, and movement patterns was established for use by the Oklahoma Department of Wildlife Conservation. Techniques to monitor use patterns were also investigated. The research combined original field observations with data published in existing literature.

Financial support was provided by Federal Aid in Wildlife Restoration monies, Pittman-Robertson Project W-130-R, Oklahoma Department of Wildlife Conservation, Oklahoma State University, the U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

Guidance from my major adviser, Dr. John A. Bissonette, Assistant Leader, Oklahoma Cooperative Wildlife Research Unit, during the study and thesis preparation was sincerely appreciated. Dr. Paul A. Vohs, Jr., past Leader, Oklahoma Cooperative Wildlife Research Unit, Dr. Fritz L. Knopf, formerly Assistant Professor, Department of Ecology, Fisheries, and Wildlife, and Dr. William D. Warde, Associate Professor, Department of Statistics, offered many helpful suggestions during the study and served as members of my graduate committee. Many hours of statistical and computer programming assistance were logged by Dr. Warde during the analysis stage. I would like to thank them for their support.

Special thanks must be given to Donald Martin, Oklahoma Cooperative Wildlife Research Unit Technician, for his many hours of field assistance and helpful suggestions for improving the project. All personnel of the Research Unit and fellow graduate students are thanked for their involvement during the project. Special appreciation must be given to O.E. Maughan, Leader, Oklahoma Cooperative Fisheries Research Unit, who substituted for F.L. Knopf and P.A. Vohs during my oral defense. He reviewed the manuscripts and made additional suggestions for improving the thesis. Lastly, I would like to thank Cindy Weever for her encouragement and help when I needed it most.

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CHAPTER I

INTRODUCTION

This thesis is comprised of 4 manuscripts written in formats suitable for submission to national scientific journals. These manuscripts are presented as chapters in the thesis and each is complete without additional supporting materials. The manuscripts, "A track plot system to monitor habitat use" (Chapter II), "Differential use of Cross Timbers habitat by white-tailed deer" (Chapter III), and "Activity levels of white-tailed deer in Cross Timbers habitat" (Chapter IV) were written in the JOURNAL OF WILDLIFE MANAGEMENT format. Chapter V, "Home ranges of white-tailed deer in Cross Timbers habitat", was written in the format of the WILDLIFE SOCIETY BULLETIN. Chapter III is the principal paper of the thesis.

CHAPTER II

A TRACK PLOT SYSTEM TO MONITOR HABITAT USE[1]

Alternative methods to direct observation and radio telemetry location are often desirable to monitor mammalian use of habitat types. Difficulties in capturing and marking animals and the small sample size typical of direct observations of low density populations often result in insufficient data for statistical analyses. Additionally, direct observations may be biased by the animal's response to the observer.

During a study of habitat use patterns of white-tailed deer (*Odocoileus virginianus texanus*) in the Cross Timbers of Oklahoma (Ockenfels and Bissonette, ms), we developed a method using track counts to supplement data obtained through direct observation and radio telemetry location. Use of track counts to show differences in habitat use is relatively recent. Kohn and Mooty (1971) determined preferential habitat use of white-tailed deer through the association of tracks crossing roads and adjacent habitat cover types. Bloom (1978) developed an index using track counts from 10 parallel transects to determine differential deer use of an Alaskan beach-forest ecotone. Kohn and Mooty did not appear to adjust for habitat differences, while Bloom

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[1]Research conducted by the Oklahoma Cooperative Wildlife Research Unit with Pittman-Robertson funds (Project No. W-130-R) provided through the Oklahoma Department of Wildlife Conservation; in cooperation with the U.S. Fish and Wildlife Service, Oklahoma State University, and the Wildlife Management Institute.

measured the percentage area of each habitat type and allocated his transect lengths by percentage area. Additionally, behavioral differences (bedding, feeding, travel, etc.,) in selection of various components of the habitat by deer seem likely to render road track counts invalid. Overemphasis of movement patterns in relation to general habitat use of a given area through road counts could lead to incorrect or misleading conclusions.

EXPERIMENTAL DESIGN

Three study sites within the post oak-blackjack oak habitat type (Duck and Fletcher 1943), commonly referred to as the Cross Timbers, were delineated into 4 major vegetative components: 1) bottomland or riparian forest, 2) upland forest, 3) brush-savanna, and 4) grassland, and then further subdivided. One hundred track plots/site were allocated proportionally to cover type, based on percentage area of the delineated components.

Field Procedure

Plot locations were determined by use of a grid system overlaid on aerial photographs (1:11,500, May 1978) and a random numbers table (Zar 1974). Since animal trails are avenues of travel from 1 area to another, we avoided placement of plots on trails to reduce the influence of movement patterns on general habitat use.

A rear-bladed roto-tiller was used to cut plots (1x3m) close to roads, while more distant plots were cut by shovel. Each plot was cut to a depth of 10 cm, raked smooth, and field flagged to facilitate relocation. Data were collected regularly (weekly) and included total number of deer tracks, estimated number of deer visits, and occurrence of other species by plot. Following data collection, each plot was cleared, initiating a new time interval. Heavy rain or snow also initiated new periods.

ANALYSIS

Comparison of actual versus expected use of the plots was examined by Chi-square analysis. Expected values were equivalent to percent area of a cover type per site. Use was determined by number of plots with tracks (frequency) and the number of tracks within a plot. For each reading period, plots with tracks were summed by cover type and the percent frequency calculated for each type. For example, during May 1979, 30 of 100 plots on Hunt Creek received deer use in an 8-day period. Ten plots were in riparian, 7 in upland forest, 5 in grassland, and 8 in other types. Frequency of use (FOU) of riparian habitat during this period was 10/30=33.3%, while upland and grassland received 23.3 and 16.7%, respectively.

FOU values do not readily account for differences in time intervals between readings caused by inclement weather or other reasons, therefore a tracks/day (TPD) value was calculated (Table 1). This value provided a measure of relative use within a cover type and allowed for differences between reading dates.

Since 100 plots were established on each site proportional to cover type availability and randomly located, we considered deviations from 1% use (number of tracks) per plot to be indicative of differential use of the habitat. Non-use of a plot was suggested if the plot value was less than 1% of the study area total. Use of individual plots, as measured by percentage of TPD or FOU by site, can be helpful in the evaluation of environmental factors (distance to water, distance to cover, etc.,), in relation to use, or can illustrate the configuration of use over a given area (Fig. 1). Area between plots was included if adjacent plots received greater than 1% use.

DISCUSSION

Potential Use

Habitat use patterns of various mammalian and avian (turkey) species, particularly white-tailed deer (Ockenfels and Bissonette, ms) have been evaluated by track counts during our study. Differences in habitat use by season, as well as within-season variability, can be monitored. For example, 11 months of monitoring were completed on Hunt Creek between November 1978 and December 1979. Seasons of use were based on phenological changes (rutting, fawning, etc.,) in white-tailed deer, as described in the literature (Severinghaus and Cheatum 1956, Hawkins and Klimstra 1970, Halls 1978, and others). Six seasons were used to evaluate deer use: 1) winter (1 Jan-28 Feb), 2) spring (1 Mar-14 May), 3) fawning (15 May-14 Jun), 4) summer (15 Jun-31 Aug), 5) pre-rut (1 Sep-30 Sep), and 6) rut (1 Oct-31 Dec). Figure 2 illustrates the seasonal use patterns of riparian, upland forest, and grassland cover types on the Hunt Creek site. Riparian use was found to increase from fawning until pre-rut, then drop sharply during the rut. Generally, use of riparian areas was more than expected (% area occupied), while upland use was more variable. Use of upland forests increased until spring, decreased during fawning, summer, and pre-rut, then rebounded sharply during the rut. This increase in upland use coincided with acorn drop. Grassland use was always less than expected. We found differences ($P<0.20$) in season use patterns of 6 of 7 cover types on Hunt Creek during the study.

Influences of outside disturbances, such as hunting and forestry practices, on white-tailed deer have been monitored by track counts (Ockenfels and Bissonette, ms). Effects of disturbances on deer activity were estimated by relating changes in TPD values to onset and cessation of outside activities.

The 1st occurrence of fawn tracks in plots enabled us to establish fawning time (1 Jun-5 Jun) and to identify fawning areas. Future research relating to fawning areas can be initiated from baseline data established by track plot counts.

Statistical Considerations

Chi-square analyses are questionable if expected values are small (Snedecor and Cochran 1967), since the assumption of normality is then violated. In this case, the data are collapsed into fewer cover types to maintain larger expected values. If small mapping units are used, design of Chi-square analyses to produce conservative estimates is possible by use of an appropriate $\underline{N}$. We used number of plots (100) as the experimental unit and therefore the $\underline{N}$ in the Chi-square model

$$\chi^2 = \Sigma \frac{(O_i - N\,P_i)^2}{N\,P_i}$$

where O_i=observed use of the habitat type, $\underline{N}$=total number of observations, and P_i=probability of occurring in the habitat type.

Paired *t*-tests (Snedecor and Cochran 1967) indicated that percent TPD and FOU were different ($P<0.20$) in 15 of 32 habitat comparisons, whereas 5 indicated equivalent values ($P>0.80$). FOU can provide rough estimates of use, but because FOU cannot account for differences in time intervals between readings and does not measure relative use within a cover type, we believe TPD values are better estimators of use. Radio telemetry data were also compared to TPD and FOU. Percentage of locations during reading intervals differed from TPD ($P<0.05$) and FOU ($P<0.05$) in 8 habitat comparisons. Due to small numbers of locations of collared deer within the intensive study site, radio telemetry data were inadequate to monitor use patterns.

Time and Fiscal Considerations

Forty-eight man-hours were required to establish plots on each study site. The time necessary to complete each reading was determined by study site size, topography, accessibility, and plot dispersion within the area. After plot locations were learned, approximately 5-8 man-hours were required to read plots on each study area. Field flagging reduces location time, but may result in the observer establishing trails. We suggest routes between plots be varied.

Increasing time intervals between readings reduces time and fiscal expenditure of personnel, but increased variability of weather within long time intervals (>10 days) is a drawback, as we found a significant association between activity levels and mean minimum (R^2=0.29, P=0.0056) and mean maximum (R^2=0.25, P=0.0145) temperature during sampling periods. Additionally, selection of cover types was significantly ($P<0.001$) affected by changes in ambient temperature for 7 radio telemetered deer. Intervals of 6-8 days appeared to be adequate for monitoring habitat use patterns and activity levels of white-tailed deer.

CONCLUSION

Evaluation of habitat use patterns by track plot data is an additional alternative to methods currently utilized by wildlife biologists. A method other than fecal group analysis is needed in the southern Great Plains and southeast, as attempts to use pellet group indices have proved unsuccessful in the region (Overton 1979). Habitat use studies utilizing radio telemetry location and pellet group are generally monospecific in design, whereas track count indices for many species can be collected concurrently by our method if desired. Information on human-related activities (cattle grazing, dog trails, hunting, etc.,) can also be collected by track counts and the influences monitored. This design allows for evaluation of land resources use by various species of wildlife, through time, on a given area.

Acknowledgements.--We thank D. Martin for field assistance and helpful suggestions in modifying the original design, P. A. Vohs and F. L. Knopf for input into the original design and manuscript review, W. D. Warde for statistical assistance and manuscript review, and J. Gray for clerical assistance.

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Table 1. Example of data computation using percentage tracks/day (TPD) to evaluate habitat use patterns of white-tailed deer on the Hunt Creek study site during May 1979.

Cover Type	Plot Number	Number of Tracks	Number of days	Tracks per day	Percent of total
Brush-savanna	117	6	7	0.86	
	146	4	8	0.50	
	182	9	7	1.29	
	198	15	7	2.14	
				4.79	10.0
Burn	139	8	7	1.14	2.4
Cultivated	166	10	8	1.25	2.6
Grassland	138	2	7	0.29	
	163	1	7	0.14	
	178	81	8	10.13	
	196	9	7	1.29	
	197	5	8	0.63	
				12.48	26.2
Riparian	104	19	8	2.38	
	106	6	7	0.86	
	112	13	8	1.63	
	118	30	8	3.75	
	125	19	8	2.38	
	132	7	7	1.00	
	137	27	8	3.38	

Table 1. Continuation.

Cover Type	Plot Number	Number of Tracks	Number of days	Tracks per day	Percent of total
	159	12	8	1.50	
	161	1	7	0.14	
	165	10	8	1.25	
				18.27	38.4
Upland forest	121	5	7	0.71	
	140	4	7	0.57	
	149	2	7	0.29	
	150	2	8	0.25	
	158	14	7	2.00	
	172	8	7	1.14	
	199	8	8	1.14	
				6.10	12.8
Wetland	100	11	7	1.57	
	154	14	7	2.00	
				3.57	7.5
				47.60	100.0

LIST OF FIGURES

HUNT CREEK

DEER USE

U: UPLAND

R: RIPARIAN

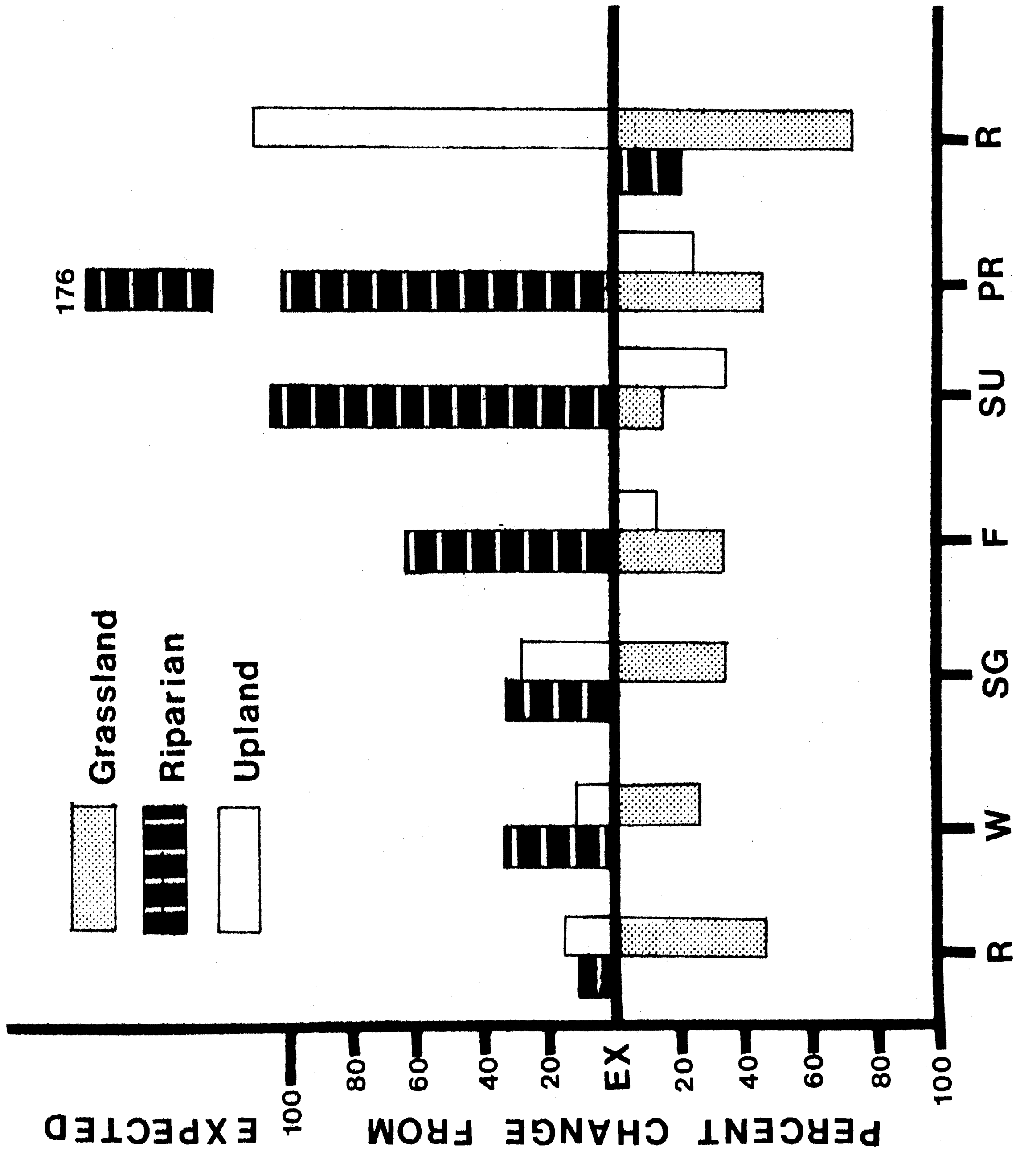
B: BRUSH-SAVANNA

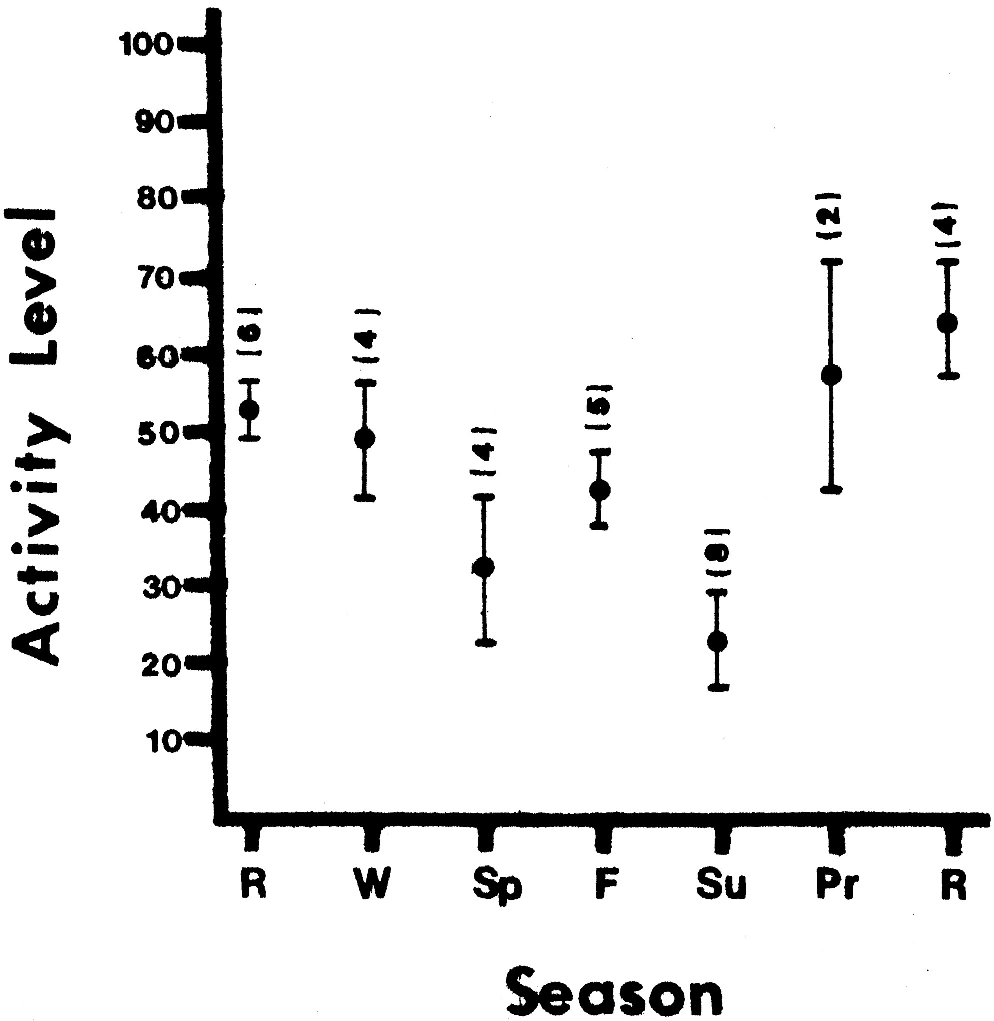
G: GRASSLAND

C: CULTIVATED

W: WETLAND

X: BURN


Grassland
Riparian
Upland
176
R
W
SG
F
SU
PR
R
100
80
60
40
20
EX
20
40
60
80
100
PERCENT CHANGE FROM EXPECTED



Activity Level
100
90
80
70
60
50
40
30
20
10
(6)
(4)
(4)
(5)
(8)
(2)
(4)
R
W
Sp
F
Su
Pr
R
Season

CHAPTER III

DIFFERENTIAL USE OF CROSS TIMBERS HABITAT BY WHITE-TAILED DEER[1]

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Abstract: Differential use of vegetative cover types by white-tailed deer (*Odocoileus virginianus*) was monitored in the Cross Timbers region of Oklahoma during 1978-79 using track counts and radio telemetry location. Use patterns on 3 study sites were determined from the number of tracks occurring in 100 track plots (1x3m) proportionally allocated by percent area of cover types. Patterns of cover type use in 23 of 25 monthly comparisons differed ($P<0.20$) from random. Ambient temperature, land-use practices, protective cover, interspersion of cover types, and food availability influenced use patterns. No one factor determined the relative use of habitat components throughout the study period.

White-tailed deer occupy many habitat types (Hirth 1977, Halls 1978), but some habitat components appear preferred within any geographical area. Various hypotheses explaining differential use of habitat components appear in the literature. Some authors (Shaw 1962, Segelquist and Green

[1]Research conducted by the Oklahoma Cooperative Wildlife Research Unit with Pittman-Robertson funds (Project No. W-130-R) provided through the Oklahoma Department of Wildlife Conservation; in cooperation with Oklahoma State University, U. S. Fish and Wildlife Service, and the Wildlife Management Institute.

1968, Kohn and Mooty 1971, and others) suggest the availability of food resources influences patterns of habitat use. Limited availability of food has a persuasive effect upon habitat selection, but other factors become important as food resources become more abundant. Vegetative properties of the habitat (cover, successional stage, and interspersion of components) appear to modify use patterns. Protective cover and food availability influenced habitat use concurrently in Idaho (Shaw 1962) and Oregon (Suring and Vohs 1979). Deer use early successional stages, i.e., brush-forest stages, more than extensive stands of mature forest (Allen 1954, Severinghaus and Cheatum 1956), while vegetative interspersion within a habitat affects relative use of components by deer (Leopold 1933, Allen 1954, Severinghaus and Cheatum 1956). Climatic parameters (Rongstad and Tester 1969, Moen 1976), land-use practices (Zagata and Haugen 1973, Suring and Vohs 1979), and changes in deer phenology, i.e., fawning and rutting, (Dasmann and Taber 1956, Hawkins and Klimstra 1970) also influence deer use patterns. Attempts to ascribe white-tailed deer habitat preference and use to a single factor have not been satisfactory and management practices based on limited findings have usually had limited success. Identification of all discernable factors influencing use of a particular habitat type is desirable before habitat modifications are undertaken. This requires the documenting of use patterns throughout a year, because seasonal changes in use may be due to shifts in the relative effect of each factor.

In this study we attempted to: 1) document habitat use throughout an annual cycle, 2) identify factors influencing the selection and avoidance of various vegetative components, and 3) make management recommendations for modification to maintain or maximize deer numbers within the habitat type studied.

We are especially grateful to D. Martin for field assistance throughout the project, D. Savage, R. Latham, and the Oklahoma Department of Wildlife Conservation for use of study sites, P. Hegdal and G. H. Matschke, USFWS Denver Wildlife Research Center, for suggestions on capture and radio telemetry techniques, and A. A. Kocan and students for helping handle captured animals. F. L. Knopf and P. A. Vohs aided in the original experimental design, while W. D. Warde provided statistical assistance. F. L. Knopf, W. D. Warde, and P. A. Vohs reviewed the manuscript and J. Gray provided clerical assistance.

STUDY AREA

The post oak-blackjack oak habitat type (Duck and Fletcher 1943), commonly referred to as the Cross Timbers (Dyksterhuis 1948), occupies 2.5 million ha in central Oklahoma. Classified as a forest grassland, the forest type occupies more area than all remaining forests in Oklahoma combined (Duck and Fletcher 1944). Stands of post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) are situated on rolling to hilly sandstone uplands (Dwyer and Santelman 1964). Areas of grassland and bottomland forest are interspersed among the stands. See Rice and Penfound (1959) and Risser and Rice (1971) for vegetative distribution and descriptions.

Three sites were selected for intensive study and contained different proportions of 4 major vegetation types: 1) bottomland or riparian forest, 2) upland forest, 3) brush-savanna, and 4) grassland. The Okmulgee site (OK, 259 ha) was dominated by upland forest (79% of total), South Hiway (SH, 92 ha) by grassland (38%), while Hunt Creek (HC, 373 ha) contained a highly interspersed mixture of the 4 types.

METHODS

Aerial photographs (1:11,500, May 1978) were used to delineate cover types (Table 1) within the 3 study sites. Boundary lines were verified by ground reconnaisance before transfer to base maps. Percent area of each cover type (Table 2) was calculated with an electronic digitizer.

Study animals were captured with Stephenson box traps from December to March, while drug immobilization techniques were used in other months. Deer were collared with color-coded activity mode transmitters (Wildlife Materials, Inc., LP23300 HDA) and cattle type ear-tags and color-coded ear streamers were attached for identification.[1]

Direct observations of marked and unmarked deer were recorded on field sheets. Data consisted of site, date, time, weather parameters, sex and age class observed, location by Cartesian coordinates, cover type, disturbances, and observed activity.

The radio telemetry system consisted of known-point stations and a reference beacon, coupled with a roof-mounted null-peak antenna for mobile tracking (Hegdal and Gatz 1978). Station number, beacon angle, and angle to animal were recorded with data similar to direct observation data. Locations were determined by plotting angles on acetate overlays of ASCS aerial photographs (1:7,920). Cover type and the appropriate coordinates were recorded. Handheld Yagi antenni were also used to periodically locate animals.

A track plot system (Ockenfels and Bissonette, ms) was used to evaluate habitat use patterns. One hundred plots per site were proportionally allocated by percent area of cover type, and randomly

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[1]Use of a product does not imply endorsement by agencies involved.

assigned within a cover type. Plots (1x3m and 10cm deep) were established by a roto-tiller and raked smooth. Data collected at regular (weekly) intervals included total number of deer tracks, estimated number of deer visits, and occurrence of other species by plot.

Chi-square analyses were used for comparisons of observed versus expected use of cover types. Differences in percent use of cover type by monthly periods were tested by Analysis of Variance (ANOVA) and Least Significant Difference (LSD) (Snedecor and Cochran 1967). An arcsine transformation was used to help normalize the data and reduce heterogeneity of variance. Effects of ambient temperature on habitat use were tested by weighted ANOVA. Because of sample size differences within the classes tested, data were adjusted by an arcsine transformation utilizing sample size

$$\underline{Y=2*SQRT(n)*ARCSIN(SQRT(COV/100))}$$

where *n*=sample size for class and COV=percent use of cover type within the class. Use of this adjustment resulted in the class *SS* of the ANOVA table being equivalent to a Chi-square value with class degrees of freedom.

Climatic records from the nearest recording station (Stillwater) supplemented field recordings.

RESULTS AND DISCUSSION

Six of 8 deer captured by box trapping (Cottonseed meal as bait) were fitted with radio transmitter packages. Habitat usage relative to expected usage was evaluated during 13 monthly periods (November 1978 to December 1979). Track count data for 66 readings (6,600 plots) on 3 sites indicated that observed use was different ($P<0.20$) from random.

Twenty-three of 25 monthly comparisons (HC=11, OK=8, SH=6) were different ($\underline{P}<0.20$) from expected values based on percent area of the various cover types. ANOVA and LSD testing of track plot data showed significant differences in use for 9 of 18 (HC=4 of 7, OK=5 of 6, SH=0 of 5) cover types (Table 2). Within-month variability was probably due, in part, to lack of controls over existing land-use practices, and the variable weather patterns of Oklahoma.

Weather effects.--Figure 1A illustrates the variability of weather parameters in central Oklahoma (U. S. Dept. of Commerce 1978, 1979). Maximum and minimum temperatures were plotted at 5-day intervals from 28 October 1978 to 9 June 1979 to show the general trend and variability within a short period. The occurrence of precipitation also influences the use patterns of cover types within a monthly period. For example, severe flooding of riparian areas at OK decreased the TPD value for the cover type during June-July in 1979, a period in which riparian forests were heavily used at HC. However, similarities between sites were present and a general pattern of use was evident.

Ambient temperature had a significant ($\underline{P}<0.001$) effect on habitat use of cover types (Fig. 1,B). Moen (1976) demonstrated that deer in northern areas conserve energy at extremely low temperatures by reducing climatic-related heat losses. He noted that areas of heavy cover and wind protection were favored by white-tailed deer during harsh weather periods. Our data suggest a decrease in upland use during low temperature periods, with a corresponding increase in riparian use. This may be due to the lack of adequate cover plants in the understory of uplands. Riparian areas have relatively abundant understory species and are more sheltered due to topography. Severe winter conditions appear to be less of a problem for southern deer than those reported for northern states, since periods of snow cover are fewer and shorter in duration.

High ambient temperature (> 30 C) has been found to adversely affect white-tailed deer (Short and Newsom 1969) and most domestic ruminants (Church 1971). Church noted that temperatures in excess of 30 C are capable of producing heat stress in livestock. A significant ($\underline{P}$<0.05) shift in cover type usage was observed at temperatures exceeding 30 C (Fig. 1,B). High mean maximum temperatures for June-September (in excess of 30 C) at the sites appeared to increase the proportion of tracks found in riparian areas during those months.

Land-use practices.--In Oklahoma upland forests and brush-savanna areas are commonly cleared to increase the grazing capacity. Clearing of the upland forest during the late fall at SH suppressed deer activity levels (tracks/day for the 100 plots) during December. The amount of use (TPD) decreased progressively, from 26.6 to 8.5, during the month. This decline in relative use of the site was short-lived, as the activity level rebounded to 37.5 TPD in early January, a greater than fourfold (4.4) increase from late December. Additionally, upland forest use increased 56.4% (31.7 to 72.7%) from December to January. This increase in activity level and upland use was probably due to the increased availability of food resources in the form of mast and foliage of fallen oaks. The length of time cutting back of upland forests benefits deer is unknown, as inclement weather prevented further monitoring of the site until mid-June.

Suring and Vohs (1979) found that grazing activities affected deer use patterns on the Columbian White-tailed Deer National Wildlife Refuge and concluded that deer preferred areas without cattle. However, they found that deer moved into area previously grazed, due to new growth of food resources. Our data suggest similar avoidance may be occurring in Oklahoma, but differences due to seasonal habitat selection and cattle use could not be statistically separated.

A threefold (2.8) decrease in TPD values during November 1979 (77.9 to 27.6) on the OK site coincided with a gun deer season, suggesting activity levels as well as habitat selection may be altered drastically by hunting. Brush-savanna use increased 509% during the hunting season and appeared related to the protective cover provided by brushy areas. However, this effect appears to be short-lived. Within 2 weeks after the season closed, use approximated the pre-hunt pattern.

Protective cover.--The effects of food availability and cover on habitat use (home ranges and movements) are difficult to separate (Sanderson 1966). All of the factors we monitored were interrelated, and the discussion of one without considering the entire system may be invalid. In an attempt to measure the effect of protective cover on use patterns, we measured the distance from each plot to the nearest cover using a digitizer on aerial photographs. Simple correlation coefficients were calculated for the distance to cover in relation to the percent of tracks occurring in the plots during the study. The coefficients were significantly different from zero at HC (r=0.30, P=0.003) and at SH (r=0.28, P=0.005). Distance to cover was not statistically significant at OK (r=0.09, P=0.376), perhaps because most plots were in cover types adequate to provide concealment. Deer preferred riparian areas during periods of high and low temperatures, while brush-savanna areas were used during the hunting season.

Fawning.--Dasmann and Taber (1956) indicated that mule deer (*O. hemionus*) select dense cover during parturition. White-tailed deer are secretive during the fawning and post-fawning periods (Hawkins and Klimstra 1970), this behavior seemingly related to concealment of young. In our study, does selected areas of the greatest protective cover as fawning habitat between 15 May and 14 June. Use of brush-savanna was relatively high during this period. Differences ($P<0.20$) in monthly use of brush-savanna (Table 2) were found at OK, and similar patterns were present at SH and HC. High incidence of fawn sign in brush-savanna types at OK and SH suggest its' importance as fawn-rearing habitat.

Interspersion.--White-tailed deer occur along ecotones and avoid large blocks of any 1 vegetative type (Allen 1954, Severinghaus and Cheatum 1956), especially those lacking cover. Study site selection allowed us to monitor use patterns in relation to habitat configuration. Plots receiving greater than 1% of the tracks were inferred to occur in preferred areas, while plots receiving less than 1% were assumed to be in inferior areas. Deviations from 1% use per plot were considered indicative of differential use of the habitat, since 100 plots were randomly located on each site and read an equal number of times. Thus, each plot should receive approximately 1% of the tracks if deer used the habitat randomly. Maps of plots that received greater than 1% of the tracks suggest large expanses of upland and grassland types are not preferred by deer. The only apparent use of a block of upland occurred during the hunting season at OK.

Food availability.--Habitat use patterns of white-tailed deer were influenced by seasonal changes in available food resources. Higher use of upland forest from late September to January coincided with acorn production. Acorns and other fruits provide a concentrated nutritional base during fall and winter periods, and where available are highly preferred by white-tailed deer (Segelquist and Green 1968). Use of upland forest in November 1979 was higher ($\underline{P}$<0.20) at HC than 1978, and field observations indicated acorns were in greater abundance during 1979. Increased use of upland forest during April was probably related to food availability. Emergence of buds on overstory vegetation generally occurs during April (J. K. McPherson, pers. comm.).

Segelquist and Rogers (1974) suggested that mast yield influenced the use of cultivated fields in winter, but we were unable to detect this in our study. LSD (ANOVA) analysis showed no difference ($\underline{P}$>0.20) in deer use of cultivated fields between years with a poor (1978) and a good (1979) acorn yield. However, the TPD value for November 1978 was slightly higher than that for 1979. Cultivated fields are generally used at night (Montgomery 1963, Segelquist and Roger 1974, Larson et al. 1978) and we noted a similar pattern in the Cross Timbers. The percent of radio-telemetered relocations ($\underline{n}$=2261) of 7 deer indicated use at night (2000-0559, >5%) was several times greater than day use, (0600-1959, <2%). As fruits of mulberry (_Morus rubra_), smilax (_Smilax bona-nox_), and grape (_Vitis spp._) matured, use of riparian areas increased. The presence of mulberry and pear trees in old farm lots was found to influence deer use. A radio-telemetered female spent considerable time at these lots as fruits matured and fell.

Management Recommendations

Riparian areas should remain virtually undisturbed. Cutting of trees should be selective so as to maintain this cover type in its "natural" state. White-tailed deer appear to use riparian areas during periods of hot temperatures to maintain proper heat balance. Until research on the effects of clearing riparian areas on physiological functions and habitat use of white-tailed deer has been completed, loss of this type through cutting practices should be controlled.

Large expanses of a cover type should be broken up into irregular areas. Allen (1954) noted that the increase of interspersion by this method is beneficial to white-tailed deer, as well as for other species. Small openings in mature forests could provide supplemental winter and spring food resources if planted with cultivated crops. Fawn-rearing habitats could be increased if encroachment of brush-savanna species is allowed, or if selective cutting is used to convert the forests into openings. Encroachment of trees into prairie areas should be beneficial to deer, as these areas received little use.

Fat reserves are low in the summer (Mautz 1978) and deer increase them during fall months on mast to survive winter conditions. Minimizing human-related activities in riparian areas during summer months would prevent the further depletion of reserves by reducing the amount of disturbance, and would reduce the heat load produced by additional movements. Reducing disturbances in upland forests during the fall should allow the deer to feed more and increase their fat reserves for winter. Cutting upland forests produces a short-term benefit to deer through increased available mast and foliage (fallen trees) and creates openings into the extensive blocks of forest. However, this activity could suppress deer use of the area if cutting continues for several weeks. We believe small openings of less than 2.5 ha (Segelquist and Rogers 1974) cut into the blocks of mature forest at irregular intervals would be beneficial to white-tailed deer in the Cross Timbers region.

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Table 1. Cover types monitored for habitat use by white-tailed deer in the Cross Timbers region of Oklahoma during 1978-79.

Cover type	Vegetative community structure
Brush-savanna	Composed of 1) scattered or clumped trees >3m in height, occuring in densities such that the canopy cover (c.c.) is 10-25%, or 2) brush species >10% c.c., or 3) combination thereof
Burn	Area burned within past 2 years
Cultivated	Land cultivated for crop or food plot, or areas of man-made structures
Grassland	Grassland with <10% woody vegetation
Riparian	Bottomland hardwood forest, including species of hickory, elm, pecan, walnut, mulberry, willow, oak, and cottonwood
Upland	Predominantly post oak and blackjack oak >9m in height and >25% c.c.
Wetland	Water of at least .25 ha, being seasonally or permanently flooded

Table 2. Differences in monthly use of 7 cover types by white-tailed deer on 3 Cross Timbers sites during 1978-79, as determined by track counts. Months commonly underlined could not be statistically separated, while those in parentheses received no use and order is unimportant. ANOVA and LSD used as statistical procedure (α=0.20). Months are ranked in ascending order of use.

Cover type	Site	% Area	Monthly use (Low → High)
Brush-savanna	HC[a]	16.4	Oct Jan Nov79 Apr Jul Sep Dec78 Jun May Nov78 Aug
	OK	8.7	Dec79 Nov79 Oct May Sep Jul Aug Jun
	SH	24.4	Jan Jul Aug Dec78 Sep Jun
Burn	HC	1.0	(Sep Nov78 Jun Aug Dec78 Jan) Jul May Nov79 Apr Oct
Cultivated	HC	1.0	Apr Aug Jul Oct Sep Jun May Nov79 Nov78 Dec78 Jan
	OK	2.3	Aug May Sep Oct Jul Dec79 Nov79 Jun
Grassland	HC	34.2	Oct Sep Nov79 Nov78 Dec78 Apr Aug May Jun Jan Jul
	OK	3.4	Oct Jun Nov79 Jul Sep Dec79 Aug May
	SH	38.2	Jan Jun Sep Dec78 Jul Aug
Riparian	HC	15.1	Oct Nov79 Dec78 Jan Nov78 May Apr Jun Aug Jul Sep
	OK	6.4	Dec79 Jun Jul Nov79 Oct May Sep Aug
	SH	4.3	Jul Dec78 Aug Jan Jun Sep
Upland	HC	31.2	Jul Jun Aug Sep May Nov78 Jan Dec78 Apr Nov79 Oct
	OK	78.9	Aug Jun May Sep Jul Nov79 Oct Dec79
	SH	31.6	Sep Dec78 Aug Jun Jul Jan
Wetland	HC	1.8	Jan Aug Sep Jul Apr May Nov78 Nov79 Oct Jun Dec78
	OK	1.0	(Sep Oct Jun May Aug) Dec79 Jul Nov79
	SH	1.0	(Sep Jun Jan) Dec78 Aug Jul

[a]HC=Hunt Creek, OK=Okmulgee, and SH=South Hiway sites

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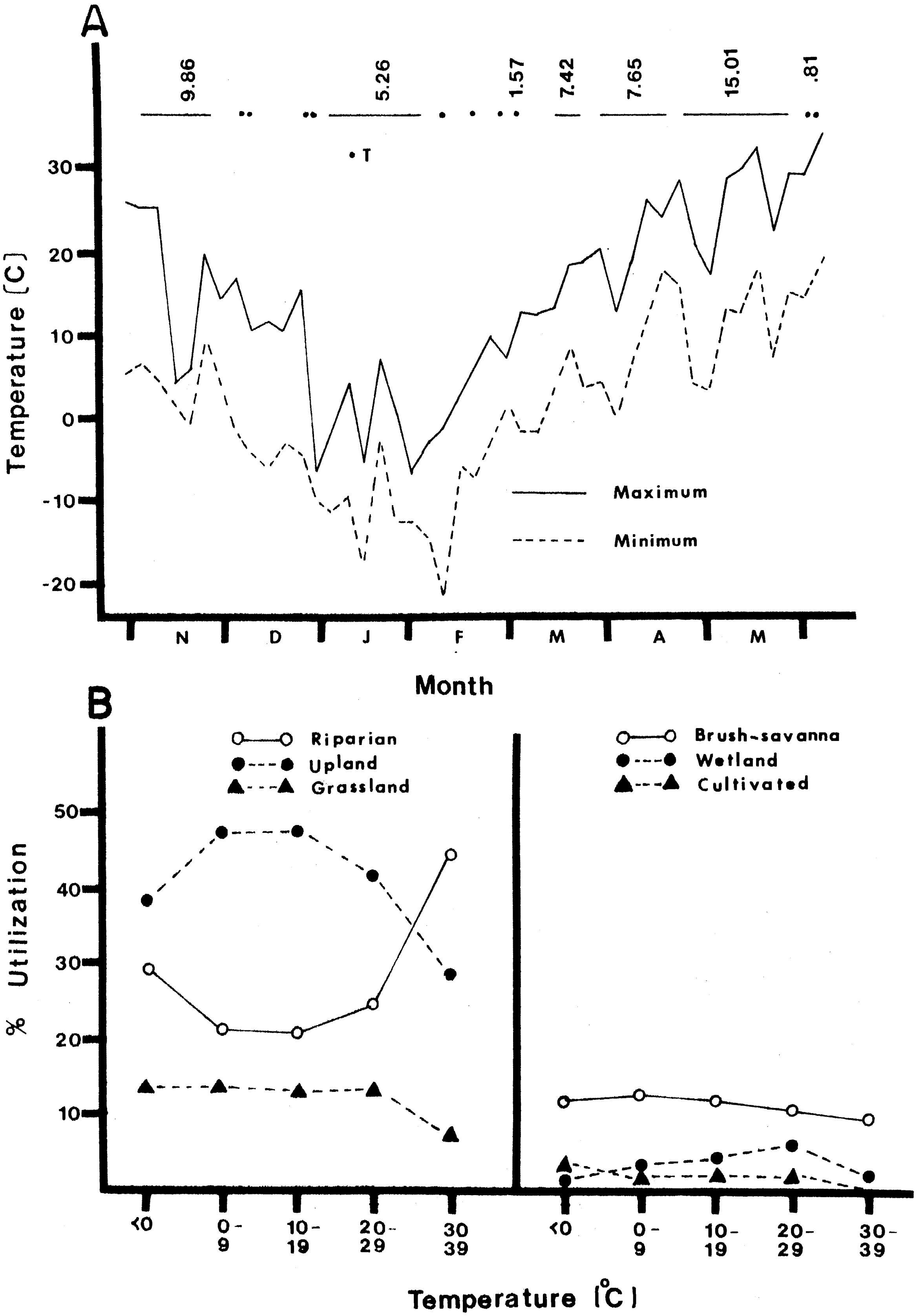
A
9.86
5.26
1.57
7.42
7.65
15.01
.81
T
Temperature (C)
30
20
10
0
-10
-20
Maximum
Minimum
N
D
J
F
M
A
M
Month
B
Riparian
Upland
Grassland
Brush-savanna
Wetland
Cultivated
% Utilization
50
40
30
20
10
<0
0-9
10-19
20-29
30-39
Temperature (°C)

CHAPTER IV

ACTIVITY LEVELS OF WHITE-TAILED DEER IN CROSS TIMBERS HABITAT[1]

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Abstract: Activity levels of white-tailed deer (*Odocoileus virginianus*) were estimated by track counts on 3 study sites in the Cross Timbers region of Oklahoma during 1978-79. An activity index (number of tracks/day) was developed from repetitive readings of 100 track plots (1x3m) per site. Within-month variability appeared to be influenced by land-use patterns, ambient temperature shifts, and changes in availability of food resources. Significant ($0.025 > P > 0.01$) differences in monthly activity levels were found. Activity was related to mean minimum ($Y=44.58+0.83X-0.0157X^2$, $R^2=0.29$, $P=0.0056$) and mean maximum ($Y=31.46+1.11X-0.0129X^2$, $R^2=0.25$, $P=0.0145$) temperatures, with activity levels being low in temperature extremes (<-10 C, >30 C). A seasonal bimodal activity pattern was found, with peaks in activity during spring and fall-early winter. Lowered activity was observed during early spring and summer. In contrast to deer living in more northern areas, late

[1]Research conducted by the Oklahoma Cooperative Wildlife Research Unit with Pittman-Robertson funds (Project No. W-130-R) provided through the Oklahoma Department of Wildlife Conservation; in cooperation with the U. S. Fish and Wildlife Service, Oklahoma State University, and the Wildlife Management Institute.

summer may be the most critical period of the year due to low quality forage and prolonged high ambient temperature for deer in the southern Great Plains.

Most information on seasonal activity levels for white-tailed deer has been reported for winter conditions in the northern United States. Ozoga and Verme (1970) reported that activity was high in December and January, decreased during February-March, and then increased during spring green-up in late March. Ingestion of food resources varied directly with activity. As forage became less palatable or abundant, more energy was required to maintain a positive energy balance. As a consequence, activity and feeding were suppressed (Moen 1976) and white-tailed deer in northern states underwent a fasting catabolism (Silver et al. 1969), often losing up to 30% of their body weight. Moen (1976) concluded that decreases in activity reduced heat loss and helped maintain an energy balance that was favorable.

We monitored activity levels of deer throughout the year in the Cross Timbers of Oklahoma. This paper presents the pattern we observed, relates changes in activity to environmental conditions, and suggests a hypothesis to account for observed changes in activity.

We thank D. Martin and other Oklahoma Cooperative Wildlife Research Unit personnel for field assistance, D. Savage, R. Latham, and the Oklahoma Department of Wildlife Conservation for study sites, and P. A. Vohs and F. L. Knopf for input into the original experimental design. F. L. Knopf, W. D. Warde, and P. A. Vohs reviewed the manuscript, W. D. Warde provided statistical assistance, and J. Gray provided clerical assistance.

STUDY AREA

The Cross Timbers region (Dyksterhuis 1948) is classified as a forest grassland, extending from Kansas through Oklahoma to Texas. Stands of post oak (Quercus stellata) and blackjack oak (Q. marilandica) grow on rolling to hilly sandstone uplands (Dwyer and Santelman 1964), interspersed with areas of grassland and bottomland forest. Descriptions of the vegetation and its distribution are given by Rice and Penfound (1959) and Risser and Rice (1971).

Three study sites were chosen: 1 located 10 km west of Okmulgee (259 ha), while the remaining 2, Hunt Creek (373 ha) and South Hiway (92 ha) were 13 km west of Stillwater.

METHODS

Activity levels of white-tailed deer were estimated by track counts taken from a track plot system (Ockenfels and Bissonette, ms) used to monitor habitat use patterns during 1978-79. One hundred track plots (1x3m, 10 cm deep) per site were allocated proportionally by area and randomly located within different cover types on 3 sites. Plots were established with a roto-tiller, and read at weekly intervals. Data collected by plot included a count of the total number of deer tracks and estimated number of deer visits. An activity index for each cover type was calculated by dividing the number of deer tracks by the interval in days since the reading was initiated. All cover type values for each site were summed, resulting in a tracks/day (TPD) value that represented the relative level of activity. Monthly TPD means ($\pm$SE) were calculated. Bartlett's test, Analysis of Variance (ANOVA), and *t*-tests were used (Snedecor and Cochran 1967). We tested the effect of ambient temperature (mean minimum and maximum) on general activity levels by multiple regression analysis (Statistical Analysis System, Barr and Goodnight 1972).

Data from the 3 sites were combined to construct a generalized pattern of activity levels for deer in the Cross Timbers. Monthly mean activity levels ($\pm$S.E.) were calculated (November 1978-December 1979).

RESULTS

Thirty-three readings (3,300 plots) were conducted at Hunt Creek, representing 50% of the total effort. Okmulgee received 17 readings, South Hiway, 16. Eleven, 8, and 6 monthly mean TPD values were calculated at Hunt Creek, Okmulgee, and South Hiway, respectively (Fig. 1).

Okmulgee's seasonal pattern of activity was 10-14 days behind Hunt Creek and South Hiway, thus, statistical tests were not performed on combined data. Additionally, December 1978 data from South Hiway were not used in the calculation of the generalized pattern for the Cross Timbers (Fig. 1, shaded area), since intensive forestry practices altered overall deer use of the site. Upland forests were cleared to increase pasture areas, suppressing use 68% (26.6 TPD to 8.5 TPD).

We analyzed the Hunt Creek data for differences between monthly activity levels. A Bartlett's test indicated variances were not equal ($0.10>\underline{P}>0.05$) at the a priori critical value ($\alpha=0.20$). However, ANOVA indicated monthly differences ($0.025>\underline{P}>0.01$) in activity were present. For example, deer were 132% more active in December-January (51.1 TPD, SD=11.7) than in July-August (22.1 TPD, SD=22.2), representing a significant ($0.01>\underline{P}>0.005$) difference in activity between early winter and summer. With the exception of the last week in August (66.6 TPD), all July-August values were less than 18 TPD, and averaged 13.1 (SD=4.4).

Based on conclusions of Ozoga and Verme (1970), Moen (1976), and Short and Newsom (1969) on white-tailed deer and Church (1971) on domestic ruminants, we tested the relationship between ambient temperature and activity. A parabolic model was predicted a priori, with reduced activity at low and high ambient temperatures, and high activity at moderate temperatures. Figure 2 illustrates the relationship between temperature and activity during 33 sampling periods on Hunt Creek. Coefficients of determination of 0.29 ($\underline{P}$=0.0056) and 0.25 ($\underline{P}$=0.0145) were found for mean minimum and mean maximum, respectively.

A threefold (2.8) decrease in TPD during a November deer hunt (77.9 to 27.6) was noted on the Okmulgee site. A 509% increase in the use of the brush-savanna cover type (Ockenfels and Bissonette, ms) occurred concurrent with decreased activity. Percentage use of the type was 3.5 during the pre-hunt sample period, 21.3 during the hunt, and 3.8 for the post-hunt sample. The post-hunt usage represents a decrease of 82%, to within 8% of the pre-hunt sample.

Appearance of 1st fawn sign in plots was 10-14 days later at Okmulgee (27 June) than Hunt Creek (15 June) or South Hiway (14 June).

DISCUSSION

Ozoga and Verme (1970) showed that activity and food intake levels varied during winter in Michigan. High levels of activity in early winter (Dec-Jan) decreased in late winter (Feb-Mar), then increased during spring green-up (late March). Moen (1976) confirmed this pattern. In Oklahoma, activity levels peaked in November-December. Inclement weather prevented us from collecting data during February-March (Fig.1), therefore activity during late winter may have been overestimated. The 1st 2 readings in April at Hunt Creek (16.4 and 18.4 TPD) were considerably less than the last reading in January (35.0), suggesting that February and March activity levels were lower than those in early winter. However, the winter of 1978-79 was the most severe in the last 21 years, thus, a "normal" winter for the region may not suppress activity levels as severely. Winters are normally short in duration, with intermittent or no snow cover. By May, activity nearly increased to November-January levels.

An increase in activity was noted during late April and early June. We were unable to separate the effects of food availability from the influence of fawning. Presumably, both factors play important roles. A sharp increase in TPD was noted in June, with many fawn tracks encountered. An 80% increase (28.7 TPD to 51.8) from 8 to 15 June was noted on Hunt Creek, due to fawning. However the emergence of buds and forbs during spring green-up may also have influenced deer movements (Verme and Ullrey 1972).

The combined data means (Fig. 1, shaded area) indicate that activity levels in the Cross Timbers region are essentially bimodal, with peaks in activity during spring and fall-early winter. Lowered activity was observed during early spring and summer. Examination of the data indicate levels of activity at Okmulgee were delayed 10-14 days in comparison to Hunt Creek and South Hiway. Viable hypotheses for this difference include: 1) population dynamics differ in respect to density, age distribution, or sex ratio, 2) gun hunting in November interferes with rutting behavior, delaying breeding, and therefore fawning, and 3) differences in vegetative quality are present.

McCullough (1979) suggested that population dynamics influence reproductive parameters of white-tailed deer. Populations whose age structures were skewed toward younger classes tended to breed and fawn later as did populations at high densities. Additionally, hunting through its selectivity (McCullough 1979) tends to shift the age structure of a population toward the younger classes. Gun hunting was permitted at Okmulgee, but not at either Hunt Creek or South Hiway. Archery deer hunting was permitted at Hunt Creek during 1978-79, but no deer were taken. Verme (1965) found that well-fed female white-tailed deer bred 12 days earlier than poorly fed does. This tends to suggest vegetative differences may be important also in determining activity levels.

In the Cross Timbers region, activity levels appear to be lowest during July-August. Short and Newsom (1969) and Church (1971) noted that heat stress and related physiological problems associated with the stress arise if ambient temperatures exceed 30 C, with reductions in activity and food intake. Temperatures were commonly in the 30-35 C range during June-August in Oklahoma and activities were much reduced. Long-term periods of high temperature suppress activity levels, probably through lowered quality of food resources. The relationship betweem ambient temperature and activity levels (Fig. 2) suggests other factors are important in determining activity levels.

Decreases in food consumption during midsummer were noted by Short and Newsom (1969), as temperature in excess of 27 C became more frequent and longer in duration. They concluded reduction in food consumption was voluntary and created dietary deficiencies. Verme and Ullrey (1972) reported that during prolonged periods of hot weather digestibility of deer forage decreased, due to lignification of plant cell walls. In south Texas, Varner et al. (1977) found deer forage quality to be at its lowest during summer months. Crude protein, dry matter digestibility, and phosphorus were lower during this period than winter. They concluded deer are under nutritional stress in summer. Does are in peak lactation, probably catabolizing body fat to compensate for reductions in food intake, whereas bucks are in a period of maximum antler development.

The sharp increase in activity during late September and October appeared to be a response to the onset of acorn drop. Habitat use patterns changed considerably at this time (Ockenfels and Bissonette, ms). Use of upland forest increased 386% from August to October on Hunt Creek, with a similar increase for Okmulgee in September to November. Rutting behavior occurs during this period (Halls 1978) and activity level increases concurrently. Field observations of marked and unmarked deer suggest food availability was the predominate reason for the initial increase in activity levels during early fall.

Seasonal rhythms, both in terms of physical activity and physiological characteristics and function, appear to be adaptations for energy conservation (Moen 1978). Mautz (1978) describes the interrelationships between activity and physiological characteristics involved in the fat cycle of white-tailed deer. Northern deer limit activities to reduce heat losses during harsh winter conditions when the cost/benefit ratio of energy balance is large. In most cases, voluntary reduction of feeding is a response to lowered food quality (Moen 1976). This pattern appears modified in southern deer living under conditions of mild winters and hot prolonged summers. Reduction of activity appears in periods of high ambient temperatures and decreased food quality, apparently in response to heat-induced stress, rather than the conservation of heat. Therefore, different management strategies are necessary to maintain healthy deer populations in southern habitats. Whereas habitat management has been concentrated on the winter ranges in the north, deer managers in the south should concentrate habitat improvement programs on late summer ranges. In addition, future research is needed to separate the effects of heat-induced stress and low quality forage on activity levels for deer in the southern Great Plains. Habitat manipulations could be drastically different for the 2 factors.

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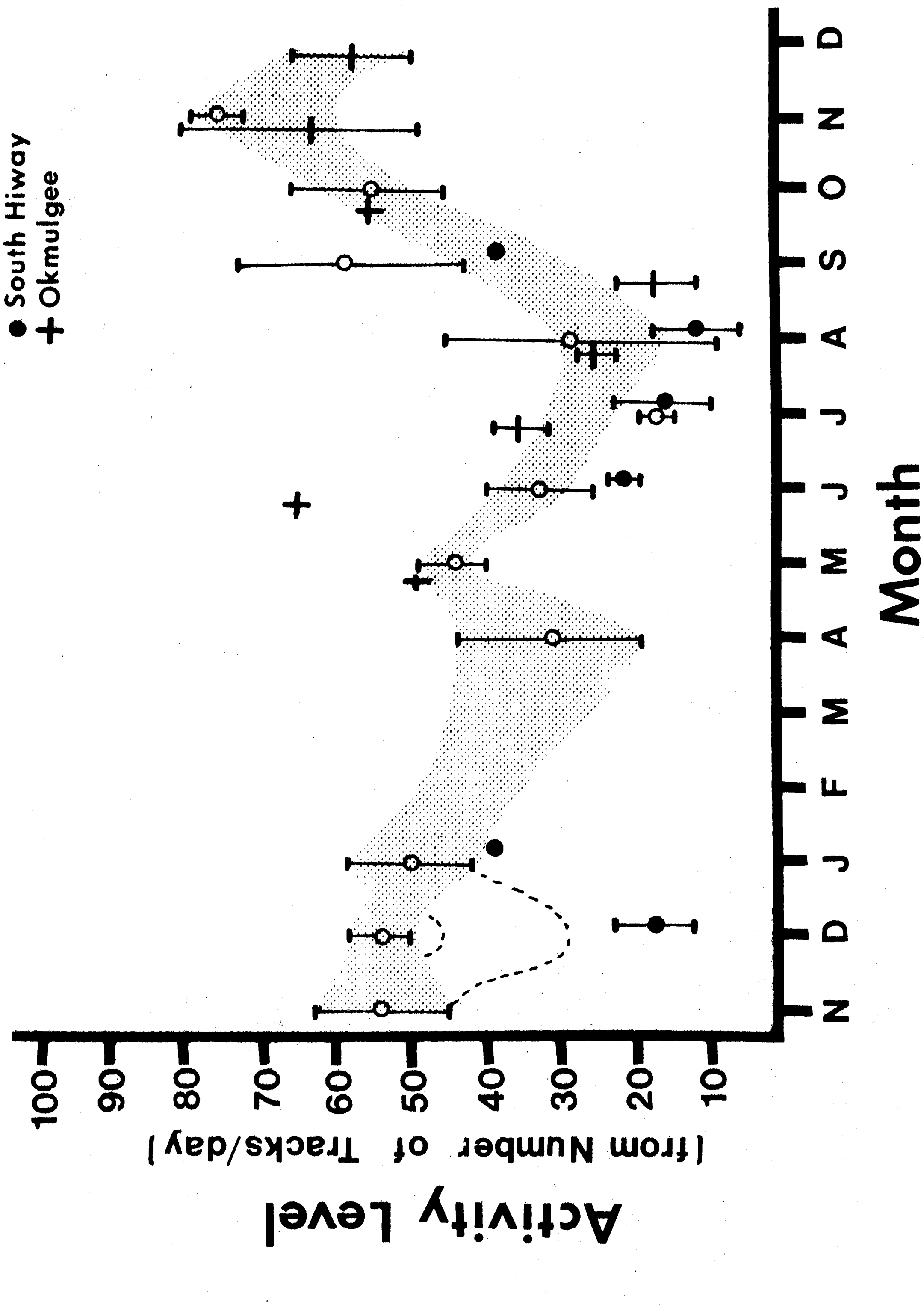
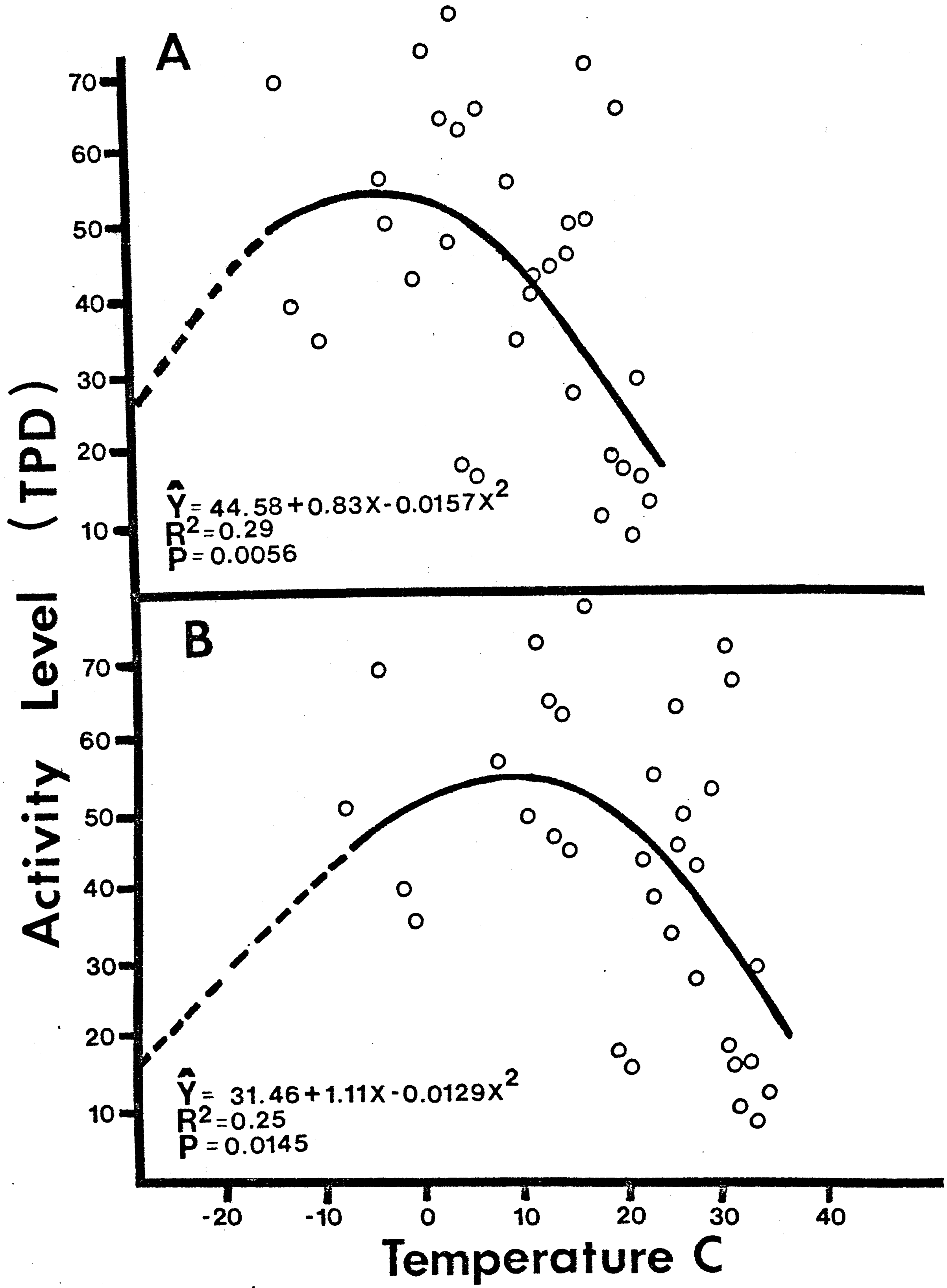

Hunt Creek
South Hiway
Okmulgee
Activity Level
(from Number of Tracks/day)
100
90
80
70
60
50
40
30
20
10
N D J F M A M J J A S O N D
Month


A
B
70
60
50
40
30
20
10
Activity Level (TPD)
$\hat{Y}$ = 44.58 + 0.83X - 0.0157X^2
R^2 = 0.29
P = 0.0056
$\hat{Y}$ = 31.46 + 1.11X - 0.0129X^2
R^2 = 0.25
P = 0.0145
-20
-10
0
10
20
30
40
Temperature C

CHAPTER V

HOME RANGES OF WHITE-TAILED DEER IN CROSS TIMBERS HABITAT[1]

Halls (1978) indicated that food resource availability influenced home range size of white-tailed deer (Odocoileus virginianus). However, home range characteristics (shape, size, etc.,) are affected by a number of factors. Habitat requirements for activities other than feeding, such as mating, parturition, and concealment, also influence the size of area needed (Burt 1943). In general, home ranges tend to increase in size as resources become less abundant (Sanderson 1966). Animals apparently travel farther to obtain the necessities of life. Comparative estimates of home range size for different habitats can provide management insight into the quality of a particular habitat type.

This paper presents data collected in the Cross Timbers region of Oklahoma during 1979. Home ranges for deer usually have been less than 300 ha in size (See Hall 1978, p. 51), with the largest (356.1) reported from Texas. Estimates of home range in the Cross Timbers are compared to these data in an attempt to indirectly evaluate the quality of the habitat type for white-tailed deer. Seasonal use areas are also presented to evaluate changes in centers of activity (preferred sites).

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[1]Research conducted by the Oklahoma Cooperative Wildlife Research Unit with Pittman-Robertson funds (Project No. W-130-R) provided through the Oklahoma Department of Wildlife Conservation; in cooperation with the U. S. Fish and Wildlife Service, Oklahoma State University, and the Wildlife Management Institute.

STUDY AREA

The Cross Timbers of Oklahoma is a forest grassland. Post oak (Quercus stellata) and blackjack oak (Q. marilandica) stands dominate hilly upland areas on sandstone soils (Dwyer and Santelman 1964). Areas of bottomland forest and grassland are interspersed with these upland sites. Our Hunt Creek study site was located 13 km west of Stillwater, Payne County, Oklahoma.

METHODS

White-tailed deer were captured in Stephenson box traps, using cottonseed meal as bait. Animals were sexed, aged (fawn, yearling, adult), weighed, and their physical condition noted. Cattle type ear-tags with attached color-coded streamers and color-coded transmitter packages (Wildlife Materials, Inc., LP23300 HDA) were used for identification.[1]

Monitoring of animals was accomplished by a system of known locations and a reference beacon, coupled with a roof-mounted null-peak mobile unit (Hegdal and Gatz 1978). Three-element Yagi antenni were used to periodically locate animals for direct observations. Station number, bearing to beacon, and bearing to animal were recorded. Locations were determined by plotting bearings on aerial photographs (1:7,920) and identified for computer analyses by assigning an alphanumeric grid code.

Areas of seasonal use and home ranges were estimated by modified - minimum area polygons as described by Hatfield (1978). This method reduced bias and was a more consistent estimator of home range size. Major axes (Hayne 1949) were also estimated. Seasons were based

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[1]Use of a product does not imply endorsement by agencies involved.

on phenological changes in activity of white-tailed deer, as described in the literature (Severinghaus and Cheatum 1956, Halls 1978, and others). Winter (1 Jan-28 Feb), spring (1 Mar-14 May), fawning (15 May-14 Jun), summer (15 Jun-31 Aug), pre-rut (1 Sep-30 Sep), and rut (1 Oct-31 Dec) periods were used to evaluate seasonal changes in home range size.

Analysis of Variance (Snedecor and Cochran 1967) was used to evaluate seasonal differences in home range size.

RESULTS AND DISCUSSION

Eight deer were captured by box trapping during the winter 1978-79. Six were fitted with transmitter packages. Due to the small sample size, we did not test for differences between sex and age classes.

Home ranges of deer were larger (9.8 km^2, SD=5.6) than those reported elsewhere (Michael 1965, Marchinton 1968, Byford 1969, Inglis et al. 1979). Seasonal shifts in the centers of activity and the size of seasonal use areas (Table 1) accounted for the increase in home range size. During the summer, deer preferred sites dominated by riparian (bottomland) forests and wetlands, while upland forests were used during fall-spring periods. Brush-savanna areas were utilized during the fawning period. This series of shifts apparently was necessary for deer to meet their requirements. For example, 2 of the deer shifted their centers of activity in winter 8.1 km west from the capture site, apparently due to the presence of winter wheat fields which were used as feeding sites. In the spring, they returned east (5 km) to an upland-riparian ecotone.

ANOVA indicated ($0.20>P\geq0.10$) that areas of deer use changed in size with phenological season. Deer did not prefer specific sites during the spring. Locations were dispersed with little clustering and the seasonal use of areas averaged 5.7 km^2. Verme and Ullrey (1972) noted movements increase in spring, apparently as a result of searching for food resources, as preferred buds and forbs emerge during this period. The extremely large area (14 km^2) covered by an adult female appeared due, in part, to attempts to locate an acceptable fawning site.

All deer used smaller areas during fawning. One female decreased her use area thirtyfold (14 km^2 to .46 km^2) from spring to fawning. However, female areas averaged 1.3 km^2, only 48% of that for the 2 males. Hawkins and Klimstra (1970) noted that adult females reduce movements during fawning season. Areas of dense cover were selected for fawning sites, 1 female restricted her area to a small creek-savanna ecotone, while another selected a riparian-savanna ecotone.

Little detectable increase in the mean area used occurred until rutting behavior was evident. Both summer (2.2 km^2, SD=1.1) and pre-rut (2.1 km^2, SD=0.8) differed little from the fawning period. However, different preferred sites were used.

Males showed twofold increases in areas of use during the rut (5.3 km^2) when compared with the summer and pre-rut. Females used a smaller area (3.5 km^2) during the rut than the males. Although upland sites were preferred during this period, locations were dispersed into other vegetative types as well.

CONCLUSION

White-tailed deer in the Cross Timbers region showed seasonal shifts in size of use areas. Large expanses of area were traveled during spring and rut, as deer searched for food resources and mates, respectively. Small, restricted areas were utilized during the fawning, summer and pre-rut periods. Fawning sites apparently required brush-savanna species for the concealment of fawns. Summer areas were dominated by bottomland forest and wetland areas, in an attempt to reduce heat-related stress from high ambient temperatures (Ockenfels and Bissonette, ms). Deer shifted from riparian areas to adjacent upland sites during the pre-rut.

Home range sizes for the southern Great Plains appear to be 2-6 times larger than those reported for other habitats. If resources are negatively correlated to home range size, the large values in Oklahoma suggest that the quality of resources is low. Deer apparently increase the size of area covered to compensate for low quality habitats.

Acknowledgements.--We thank D. Martin and other Oklahoma Cooperative Wildlife Research Unit personnel for field assistance, D. Savage for use of a study site, W. D. Warde for assistance in computer programming and statistical analyses, and J. Gray for clerical assistance. W. D. Warde, F. L. Knopf, and P. A. Vohs reviewed the manuscript and had input into the experimental design.

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Table 1. Size (km^2) of area, length (km) of major axis, and number (n) of relocations within a season and the year for 6 radio-telemetered white-tailed deer on the Hunt Creek study site during 1979.

Season	Male fawn			Female fawn			Female fawn			Male adult			Female adult			Female adult			Mean value		
	Area	Axis	n	Area	Axis	n	Area	Axis	n	Area	Axis	n	Area	Axis	n	Area	Axis	n	Area	Axis	n
Winter	1.7	2.1	31	8.0	8.6	21	.6	1.3	6				.1	.7	6	5.4	8.5	16	5.0	4.2	80
Spring	3.6	4.2	41	8.4	8.5	20	2.8	2.6	41	3.3	2.5	42	2.2	3.0	38	14.0	8.3	23	5.7	4.9	205
Fawning	2.4	2.4	55				1.6	2.4	41	3.1	2.7	60	1.8	1.9	55	.5	1.8	54	1.9	2.2	265
Summer	2.6	2.9	132				3.1	2.5	127	3.0	2.6	123	1.8	1.9	127	.5	1.1	132	2.2	2.2	641
Pre-rut	2.3	2.8	77				2.4	2.7	64	2.9	2.7	75	2.2	2.4	63	.7	1.7	64	2.1	2.5	343
Rut	5.1	4.4	133				2.7	2.9	161	5.6	4.4	124	4.2	3.3	176	3.6	3.2	129	4.2	3.6	723
Home range[a]	7.3	4.4	466	14.7	8.8	41	5.7	3.6	440	6.9	4.4	427	5.1	3.6	465	18.8	9.0	418			N=2257

[a]Composite area for home range, does not equal sum of preceding values due to overlap in use of areas.

APPENDIX A

RELATIONSHIP BETWEEN DISTANCE MOVED AND TIME PERIOD, TEMPERATURE, AND PHENOLOGICAL SEASON

Table 1. Diel movement patterns of radio-telemetered white-tailed deer on the Hunt Creek study site during 1979. Mean distance (m) is the average linear distance between sequential relocations. Maximum time period between relocations=10 hrs.

Time Period (hrs)	Mean distance (m)	Sample size (n)
0-0559	451.3	35
0600-0759	420.4	89
0800-1159	306.9	471
1200-1759	276.3	644
1800-1959	358.4	124
2000-2359	482.4	165

ANOVA and LSD testing ($\alpha=0.05$)

1200 1759	0800 1159	1800 1959	0600 0759	0000 0559	2000 2359

F=11.27 with 5/1522 degrees of freedom

P<0.0001

Table 2. Effect of ambient temperature on movement patterns of radio-telemetered white-tailed deer on the Hunt Creek study site during 1979. Mean distance (m) is the average linear distance between sequential relocations. Maximum time period between relocations=10 hrs.

Temperature Interval (C)	Mean distance (m)	Sample size (*n*)
0	350.2	26
0-9	363.2	109
10-19	414.8	263
20-29	327.0	723
30-39	257.7	406

ANOVA and LSD testing ($\alpha=0.05$)

30-39   20-29   0   0-9   10-19

F=6.76 with 5/1522 degrees of freedom

P<0.0001

Table 3. Seasonal movement patterns of radio-telemetered white-tailed deer on the Hunt Creek study site during 1979. Mean distance (m) is the average linear distance between sequential relocations. Maximum time period between relocations=10 hrs.

Season	Date	Mean distance (m)	Sample size ($\underline{n}$)
Winter[a]	1 Jan-28 Feb		10
Spring	1 Mar-14 May	485.6	78
Fawning	15 May-14 Jun	301.2	179
Summer	15 Jun-31 Aug	285.3	467
Pre-rut	1 Sep-30 Sep	326.9	290
Rut	1 Oct-31 Dec	353.1	504

ANOVA and LSD (α=0.05)

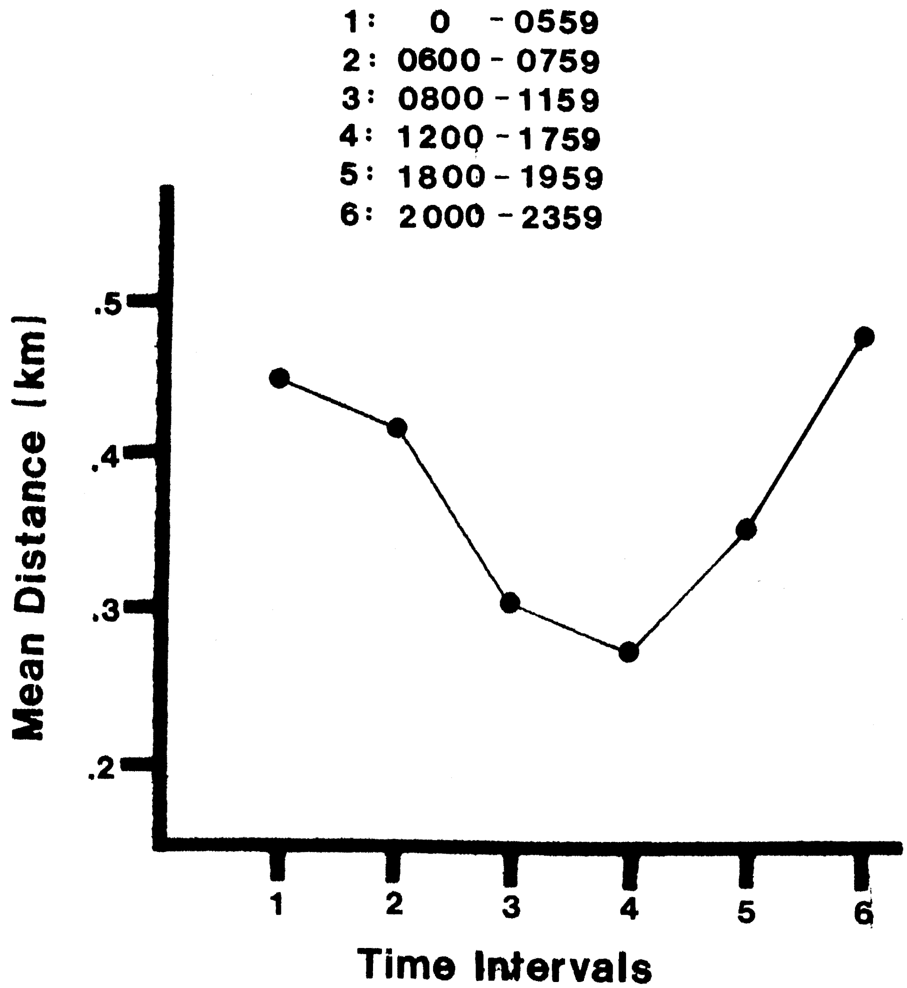
Summer Fawning Pre-rut Rut Spring

$\underline{F}$=6.14 with 4/1513 degrees of freedom

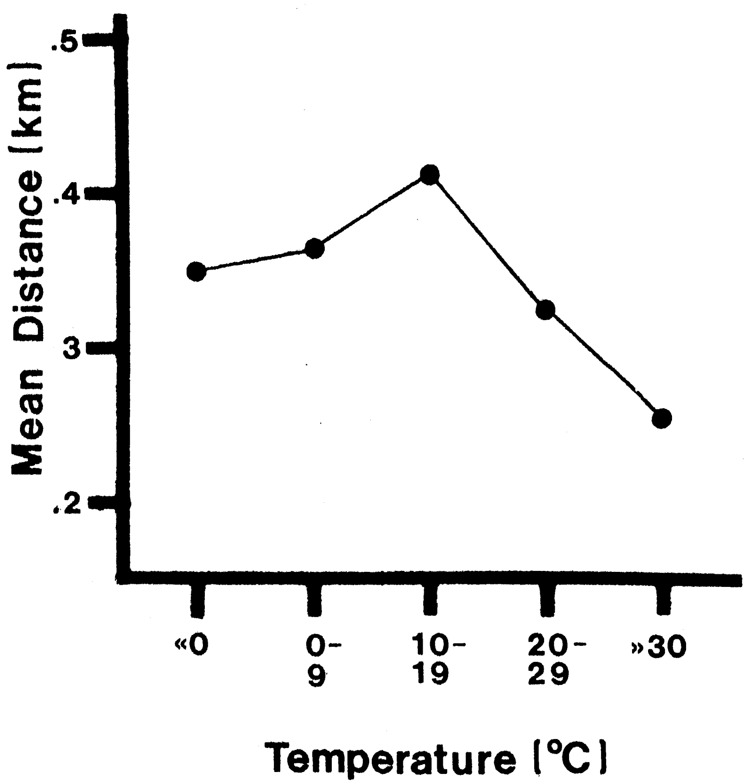
$\underline{P}$=<0.0002

[a]Winter deleted from analysis due to insufficient sample size.

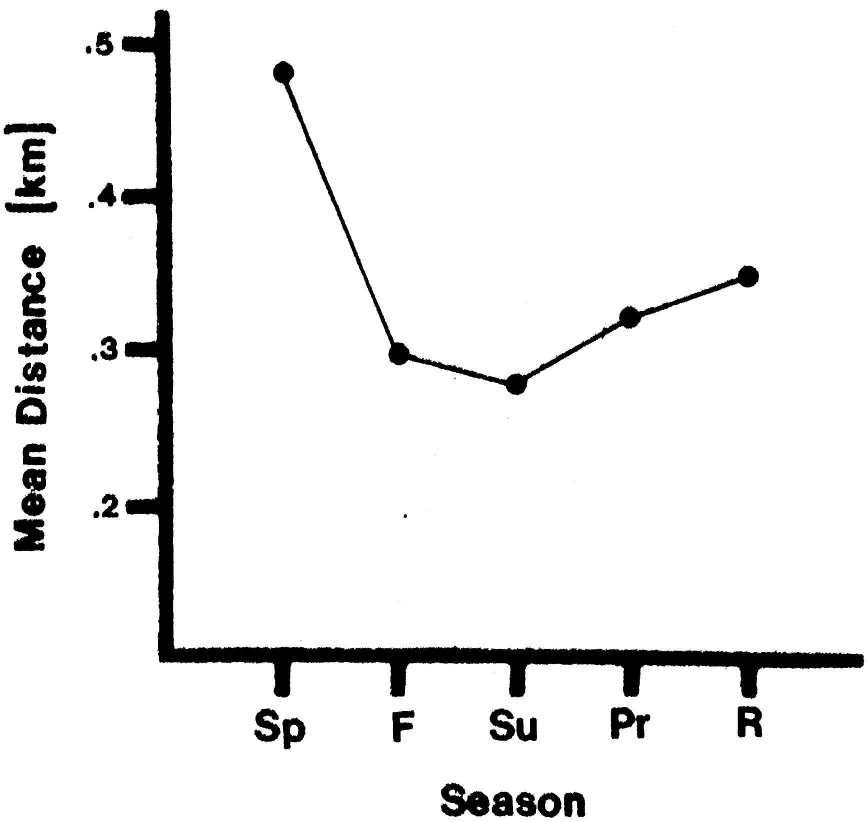
LIST OF FIGURES



1: 0 - 0559
2: 0600 - 0759
3: 0800 - 1159
4: 1200 - 1759
5: 1800 - 1959
6: 2000 - 2359
Mean Distance (km)
.5
.4
.3
.2
1
2
3
4
5
6
Time Intervals



Mean Distance (km)
.5
.4
3
.2
«0
0-
9
10-
19
20-
29
»30
Temperature (°C)



Mean Distance (km)
.5
.4
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F
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R
Season

APPENDIX B

DIEL HABITAT USE PATTERNS

OF WHITE-TAILED DEER

Table 1. Diel habitat use patterns of radio-telemetered white-tailed deer on the Hunt Creek study site during 1978-79. Percentage use and cover type calculated from the number of relocations taken during the time intervals. Unequal time periods reflect deer activity patterns in the literature (Montgomery 1963, Marchinton 1968, Halls 1978, and others, see Text).

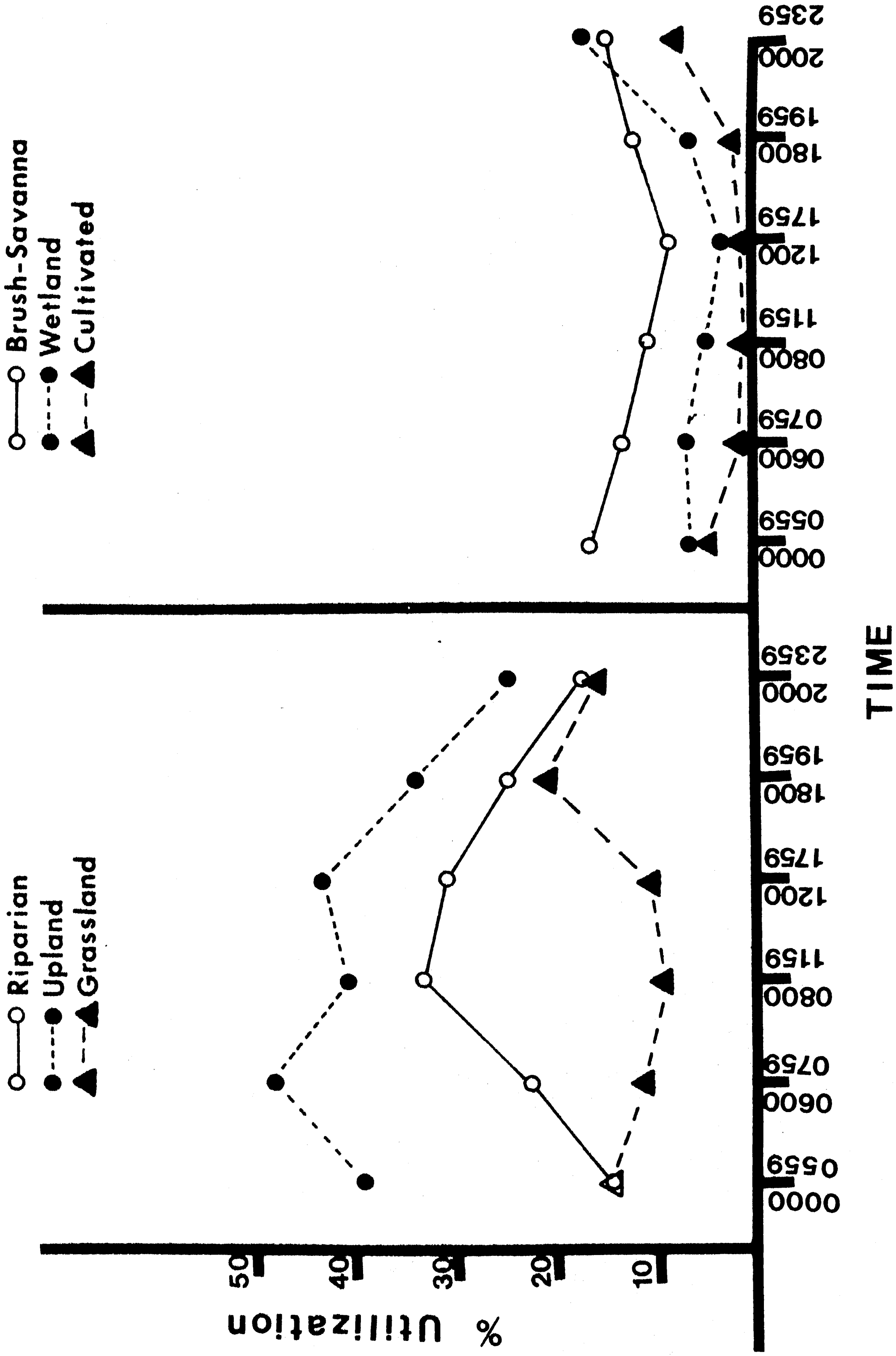
Cover types	Time periods					
	0000 0559	0600 0759	0800 1159	1200 1759	1800 1959	2000 2359
Brush-savanna	17.2	13.1	10.8	9.1	12.2	14.6
Burn			0.1			
Cultivated	5.0	1.3	0.5	1.2	1.7	7.8
Grassland	15.8	11.9	9.4	10.7	21.4	17.2
Riparian	15.8	22.6	33.6	31.6	24.3	18.1
Upland	38.8	44.8	40.9	43.6	34.1	25.0
Wetland	7.2	6.2	4.6	3.6	6.3	17.2

Test: ANOVA (weighted for sample size=resultant value=χ^2);
Arcsine transformation used; Y=2*SQRT(*N*)*ARCSIN(SQRT(COV/100));
see page 20 of text.

P<0.001

LIST OF FIGURES

Fig. 1. Diel habitat use patterns of radio-telemetered white-tailed deer on the Hunt Creek study site during 1978-79. Percentage use of cover type calculated from the number of relocations taken during the time period. Unequal time periods reflect deer activity patterns in the literature (Montgomery 1963, Marchinton 1968, Halls 1978, and others, see Text).


Riparian
Upland
Grassland
Brush-Savanna
Wetland
Cultivated
% Utilization
50
40
30
20
10
0000
0559
0600
0759
0800
1159
1200
1759
1800
1959
2000
2359
TIME

APPENDIX C

CAPTURE DATA ON WHITE-TAILED DEER

Table 1. Capture technique used and date of capture of white-tailed deer on the Hunt Creek study site during 1978-79.

Animal number	Sex	Age class	Technique	Date of capture	Recaptures
101	F	Fawn	Drugged	10-4-78	
102[a]	M	Fawn	Box Trap	12-19-78	
103	F	Adult	" "	12-29-78	
104	M	Fawn	" "	1-1-79	2-19-79
105	F	Fawn	" "	1-5-79	1-15-79 1-17-79
106	F	Adult	" "	1-15-79	
107	F	Adult	" "	2-5-79	
108	F	Fawn	" "	2-6-79	2-24-79 2-25-79
109	M	Adult	" "	2-12-79	

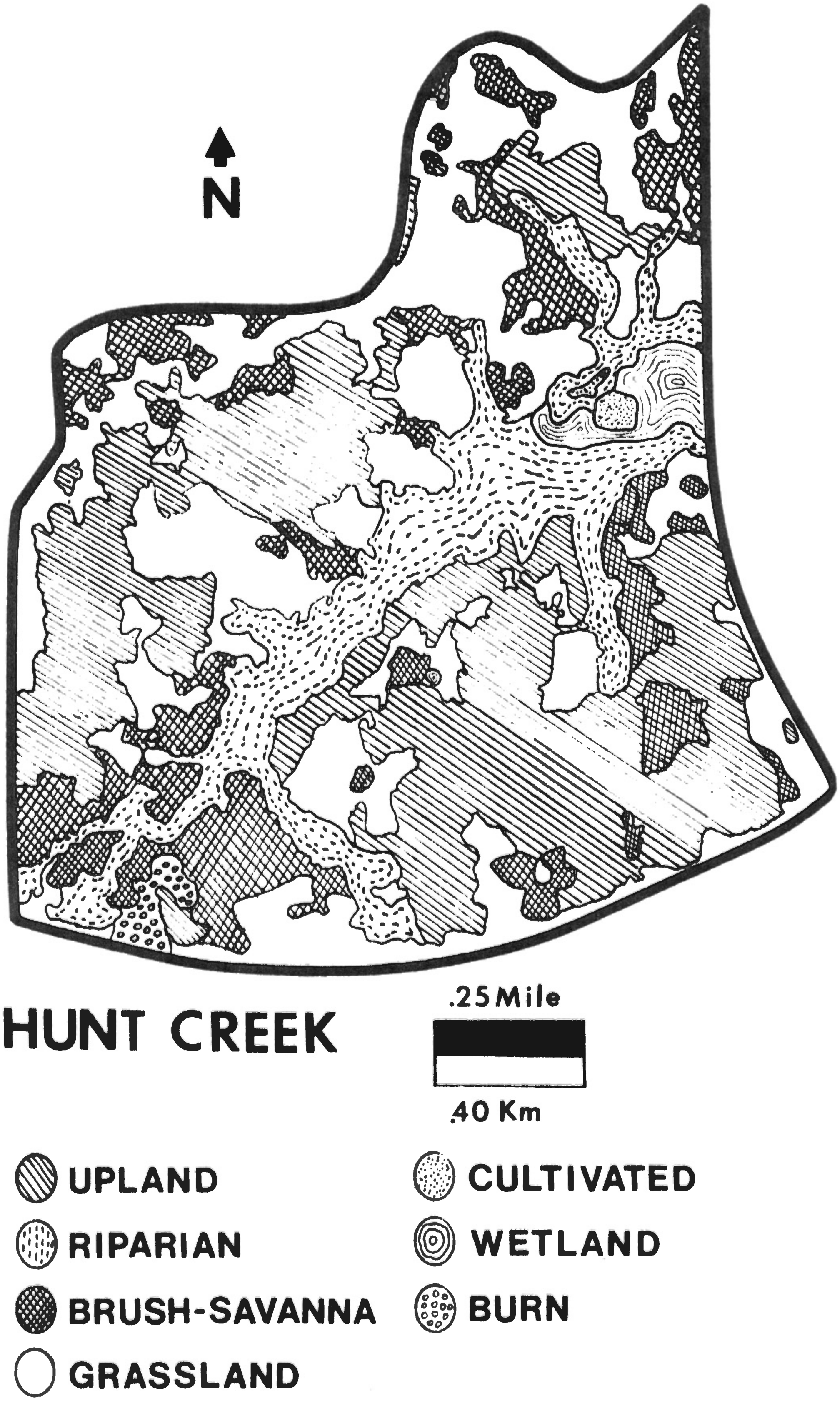
[a]Animals 102 and 103 captured together; 102 died in trap of broken vertebrate (C5), while 103 escaped.

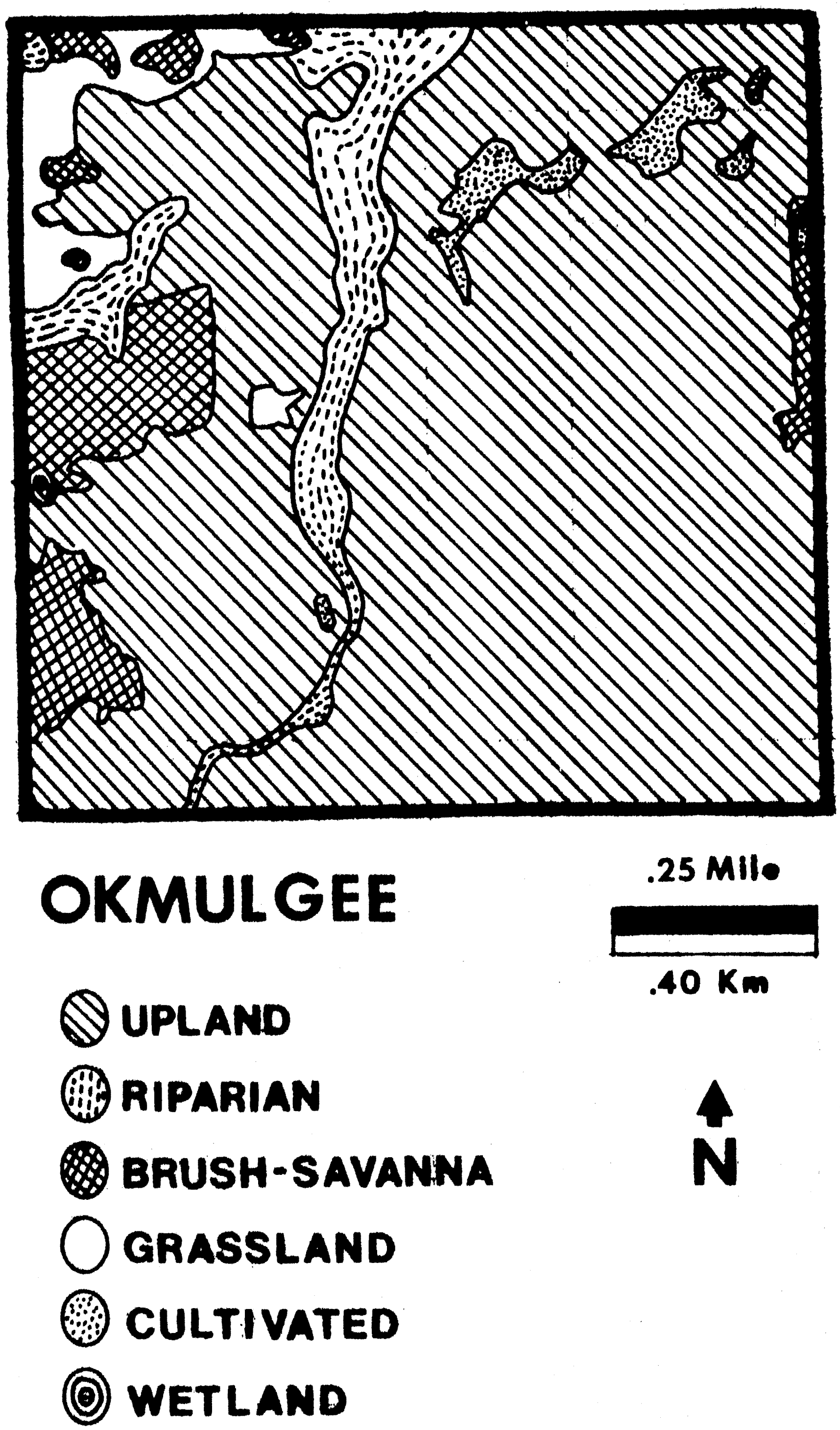
APPENDIX D

DELINEATION OF COVER TYPES

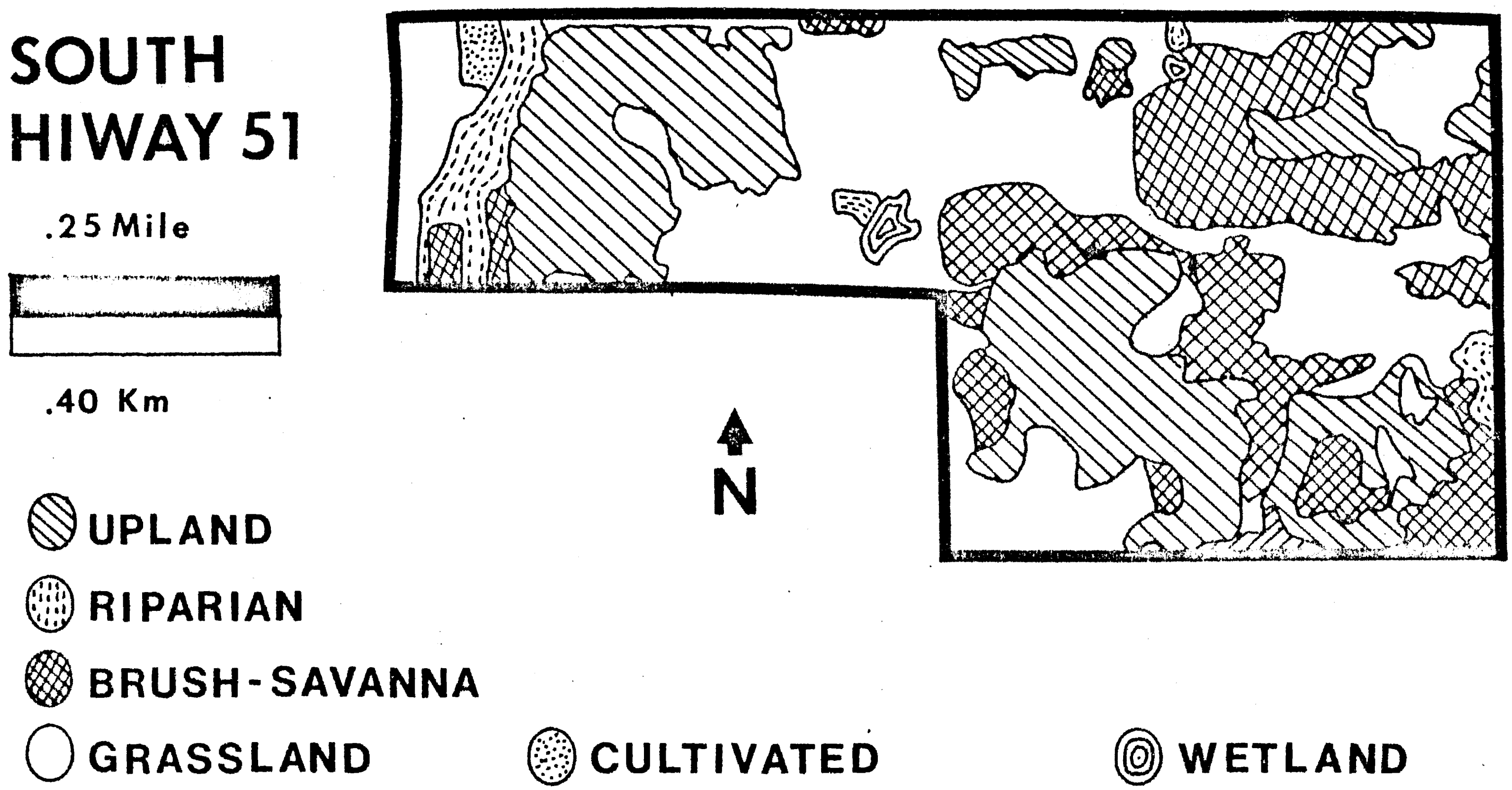
ON 3 STUDY SITES

LIST OF FIGURES


N
HUNT CREEK
.25 Mile
.40 Km
UPLAND
RIPARIAN
BRUSH-SAVANNA
GRASSLAND
CULTIVATED
WETLAND
BURN



OKMULGEE
.25 Mile
.40 Km
UPLAND
RIPARIAN
BRUSH-SAVANNA
GRASSLAND
CULTIVATED
WETLAND
N


SOUTH
HIWAY 51
.25 Mile
.40 Km
N
UPLAND
RIPARIAN
BRUSH-SAVANNA
GRASSLAND
CULTIVATED
WETLAND

VITA 2

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