1994

# Winter/Spring Population Characteristics of White-Tailed Deer in an Agricultural/Wetland Complex in Northeastern South Dakota

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## Recommended Citation

Kernohan, Brian J., "Winter/Spring Population Characteristics of White-Tailed Deer in an Agricultural/Wetland Complex in Northeastern South Dakota" (1994). *Electronic Theses and Dissertations*. 500.
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# WINTER/SPRING POPULATION CHARACTERISTICS OF WHITE-TAILED DEER IN AN AGRICULTURAL/WETLAND COMPLEX IN NORTHEASTERN SOUTH DAKOTA

BY

BRIAN J. KERNOHAN

A thesis submitted in partial fulfillment
of the requirements for the
Master of Science
South Dakota State University
1994

# WINTER/SPRING POPULATION CHARACTERISTICS OF WHITE-TAILED DEER IN AN AGRICULTURAL/WETLAND COMPLEX IN NORTHEASTERN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree in Wildlife and Fisheries Sciences and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

| | |
|---|---|
| Dr. Jonathan A. Jenks<br>Major Advisor | Date |
| Dr. Charles G. Scalet<br>Head, Department Wildlife and Fisheries Sciences | Date |

# ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Jonathan Jenks, for his insight into this project, statistical advice, and consideration for the "team". I would also like to thank my advisory committee, Dr. Lester Flake, Dr. Zeno Wicks III, and Dr. Hal Werner, for reviews of this thesis and support. Thanks also are extended to the Wildlife and Fisheries clerical staff, they make the department turn. Also a big thanks to my field assistants, Jerry Kelly, Jeff Sahli, and Kelly Petterson for their long hours, cold nights, broken trucks, and enthusiasm.

To those who have made me a better wildlife ecologist- thank you, especially Joshua Millspaugh for his objective thinking, technical knowledge, and friendship while in South Dakota, Conservation Officer Bill Antonides for his assistance in the field and friendship, Michigan State University staff, primarily Dr. Jonathan Haufler, Dr. Harold Prince, Dr. Louis Bender, and Dr. Gary Roloff. Without Gary's enthusiasm and trust during the infancy of my career I would not have accepted the challenge.

Without the assistance and support of Sand Lake National Wildlife Refuge personnel, South Dakota Department of Game, Fish and Parks Staff, Brown County private land owners, and Brown County sportsmen, this project would not have been such a success.

A special thanks to my family. Without their constant encouragement and love I would not have made it this far. Also, thanks to my Grandma Margaret Bathey for supplying me with the greatest conservation school a boy could ask for - Indian Garden Lake and her surrounding hills.

Most of all I would like to thank my wife, Tania. Without Tania's constant support, love, and willingness to settle in South Dakota my ambition would have been lost.

This project (No. 7560) was funded by Federal Aid to Wildlife Restoration Fund, Project W-75-R through South Dakota Department of Game, Fish and Parks, the South Dakota Agricultural Experiment Station, and the National Rifle Association. Support was provided by South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, and Sand Lake National Wildlife Refuge (U.S. Fish and Wildlife Service).

## ABSTRACT

# WINTER/SPRING POPULATION CHARACTERISTICS OF WHITE-TAILED DEER IN AN AGRICULTURAL/WETLAND COMPLEX IN NORTHEASTERN SOUTH DAKOTA

Brian J. Kernohan

November 1994

Habitat preference, cover characteristics of corn, movements, and sexual segregation patterns of white-tailed deer (Odocoileus virginianus) were evaluated at Sand Lake National Wildlife Refuge (SLNWR) in winter (January - March) and spring (April - June), 1993 and 1994. An average of 20 radio-collared deer were monitored per season, which resulted in 4,058 relocations. Habitat preference was assessed using 95 and 50% home range contours that were estimated using an adaptive kernel method. Agricultural crops (i.e., corn [Zea mays], row crops other than corn [e.g., soybeans [Glycine max]], small grains [e.g., wheat [Triticum aestivum]], and alfalfa [Medicago sativa]) were generally preferred in winter within the 95% home range; whereas, treebelts and dense-cover grasslands were preferred within the 50% core area. Corn, row crops other than corn, treebelts, and brome-dominated grasslands were preferred within the 95% home range in spring. Within the 50% core area, alfalfa and treebelts were preferred. Although agricultural crops were generally preferred on SLNWR, emergent vegetation and brome-dominated grasslands were important to white-tailed deer, regardless of habitat availability. Use of corn by white-tailed deer on SLNWR increased quadratically with corn height and density. Corn serves as food to white-tailed deer from early development until maturity. Corn also acts as quality cover starting when plants reach 35 - 66 cm in height until harvest. Activity (e.g., feeding, loafing) in corn varies with digestibility, density, and height of corn. Localized movements by deer on SLNWR were determined from mean 95 and 50% home ranges. Mean white-tailed deer 95% home range size was 437 ha during winter and spring. Core area movements varied depending on sex and age of deer. Males had larger core areas (i.e., 48 - 59 ha) than either yearling (i.e., 1.5-year-old) females (i.e., 22 ha) or adult (i.e., ≥ 2.5-year-old) females (i.e., 39 ha). Yearling females had the most restricted core area movement (i.e., 22 ha). Site fidelity was evaluated using multi-response permutation procedures (MRPP) and range-overlap estimates. Site fidelity between years (i.e., intraseasonal site fidelity) and between seasons (i.e., interseasonal site fidelity) on SLNWR was moderate. Sexual segregation was evaluated with respect to differential use of space and habitats using MRPP and range-overlap techniques. Deer on SLNWR exhibited moderate sexual segregation in winter and high sexual segregation in spring. However, sexual segregation with respect to differential use of habitats did not exist. Habitat preference, movements, and sexual segregation patterns on SLNWR were all affected by landscape structure (i.e., wetland/agricultural complex) and density of deer. Changing agricultural practices promote optimal interspersion of habitats while maintaining necessary juxtaposition of habitats, which drives preference, importance, and movement patterns. Management strategies to control white-tailed deer on or near SLNWR must consider all aspects of these population characteristics in order to decrease depredation complaints on private lands.

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# LIST OF ABBREVIATIONS

| Meaning | Abbreviation |
|---|---|
| Sand Lake National Wildlife Refuge | SLNWR |
| Environmental Systems Research Institute | ESRI |
| Geographic Information System | GIS |
| Root Mean Square | RMS |
| Multivariate Analysis of Variance | MANOVA |
| Analysis of Variance | ANOVA |
| Multi-Response Permutation Procedure | MRPP |

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# Chapter 1: INTRODUCTION

Since the establishment of Sand Lake National Wildlife Refuge (SLNWR) in 1935, white-tailed deer (*Odocoileus virginianus*) have increased dramatically on refuge and privately owned surrounding lands (Cook 1945). The large marsh and permanent water supply undoubtedly have been major factors contributing to high deer density on SLNWR (Cook 1945). Recently, extensive deer harvests (i.e., reduction hunts) have been conducted on the refuge to reduce damage by deer to surrounding croplands. However, landowners continue to report substantial depredation on these agriculture crops. Damage has resulted from trampling and consumption of immature and mature plants.

Close proximity of wetland refugia and accessible forage (i.e., agricultural crops) might provide conditions that have resulted in established depredation patterns. Movements of deer from the refuge to surrounding lands in spring and fall are speculative. Of primary concern to refuge managers is whether deer are remaining on refuge lands for a substantial part of their lives, or if deer are attracted to the refuge in the fall from surrounding lands and remain to breed (J. Koerner, pers. comm., U.S. Fish and Wildlife Service, SLNWR). Such a pattern might allow deer to repopulate surrounding agricultural lands in spring while limiting winter mortality.

White-tailed deer habitat use in regions characterized by intensive agriculture has been studied extensively (Zwank et al. 1979, Murphy et al. 1985, Dusek et al. 1988, Nixon et al. 1991, Gould and Jenkins 1993). However, little information is available regarding white-tailed deer habitat use in midwestern agricultural/wetland complexes. Furthermore, habitat use by a high density deer population in a refugia setting has received little attention (Nixon et al. 1991). Information regarding habitat use is critical to management of white-tailed deer on SLNWR. Knowledge of habitat use patterns would enable managers to predict movement patterns, estimate frequency of habitat use, and regulate harvest more accurately.

Sex related variation in habitat use and foraging behavior of white-tailed deer has received considerable attention (Verme 1988, McCullough et al. 1989, Beier and McCullough 1990) and could be important relative to management of deer on SLNWR. In addition to white-tailed deer, sexual segregation has been documented in several other ungulate species (i.e., elk [Cervus elaphus] [Peek and Lovaas 1968], moose [Alces alces] [Miquelle et al. 1992], mule deer [O. hemionus] [Bowyer 1984, Ordway and Krausman 1986], and bighorn sheep [Ovis canadensis] [Geist and Petocz 1977, Shank 1982]). Although documentation is extensive, causation has not been ascertained. Life requisites must be considered by sex if significant sexual segregation occurs in managed populations. Without such considerations, desired population characteristics (e.g., density, sex and age structure, and health) may not be obtainable.

Information regarding habitat use and movement of white-tailed deer is needed to enable refuge managers to effectively evaluate the deer population with respect to depredation and harvest design. Furthermore, active management of the population is necessary to curtail further depredation problems. The overall objectives of this study were: 1) to evaluate winter/spring habitat use, 2) to evaluate cover characteristics of corn (Zea mays) with respect to white-tailed deer use of corn, 3) to evaluate winter/spring movements, and 4) to evaluate sexual segregation patterns. Specific objectives are outlined in each chapter.

## STUDY AREA

Sand Lake National Wildlife Refuge is located in Brown County, South Dakota (T. 126,127 N.; R. 61,62 W.) (Fig. 1). The refuge lies adjacent to the northwest edge of the Coteau de Prairie along the James River in the James River Lowland (Westin and Malo 1978). The region is typified by gently rolling hills with an abundance of small wetlands

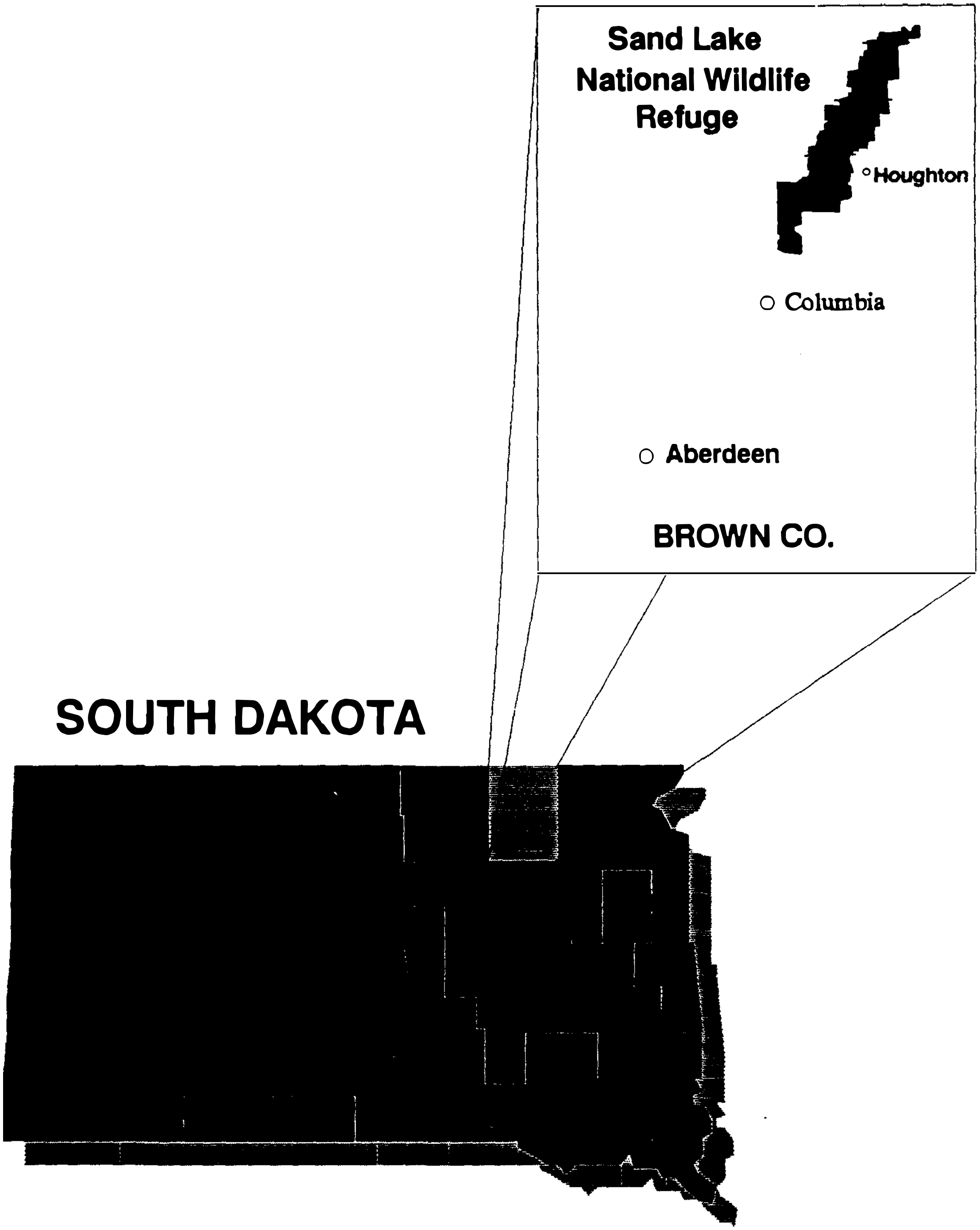

Figure 1. Map of South Dakota showing location of study area, Sand Lake National Wildlife Refuge, in Brown County, SD.

interspersed within lands converted from prairie to primarily agricultural croplands.

The Refuge is an 8,693 ha agricultural/wetland complex of which 12% is comprised of open water. The James River was impounded at Columbia grade and at Houghton grade forming Sand Lake and Mud Lake, respectively. Wetland habitats, primarily cattail (*Typha* spp.) and common reed (*Phragmites australis*), make up 45% of the refuge. The remaining area is a mosaic of shelterbelts, grasslands, and agricultural crops (Naugle et al. 1994*a*,*b*). Agricultural crops grown on or near SLNWR include corn, soybeans (*Glycine max*), small grains (e.g., wheat [*Triticum aestivum*]), and alfalfa (*Medicago sativa*). Corn is the most important crop in the area and makes up 33.5% of crops grown on SLNWR; of which, 55% remains unharvested throughout winter (J. Jave, pers. comm., U.S. Fish and Wildlife Service, SLNWR).

Climate in northeastern South Dakota is continental (National Oceanic Atmospheric Administration (NOAA) 1985). In 1987-1990, temperature extremes were -33.5°C and 37.9°C. In 1990 and 1991 average daily minimum temperatures ranged from -19°C in January to 15°C in July; average daily maximum temperatures ranged from -7.2°C in January to 29.6°C in July (Conway and Liston 1990). Average annual snowfall is 91.4 cm (NOAA 1985). In winter 1993, minimum and maximum temperatures ranged from -31°C to 3°C and -22°C to 18°C, respectively and maximum snow depth was 58 cm. In winter

1994, minimum and maximum temperatures ranged from -43°C to 2°C and -27°C to 16°C, respectively and maximum snow depth was 112 cm. In spring 1993, minimum and maximum temperatures ranged from -6°C to 18°C and 3°C to 29°C, respectively and total precipitation was 25 cm. In spring 1994, minimum and maximum temperatures ranged from -9°C to 20°C and 2°C to 32°C, respectively and total precipitation was 9 cm (B. Schultz, pers. comm., U.S. Fish and Wildlife Service, SLNWR).

## Chapter 2: HABITAT PREFERENCE AND IMPORTANCE

Knowledge of habitat use patterns are critical to management of white-tailed deer, especially in areas of high deer density. Riparian areas are important habitats for white-tailed deer in agricultural and prairie regions of North America (Harmoning 1976, Zwank et al. 1979, Swenson et al. 1983, Compton et al. 1988, Dusek et al. 1988). In southeastern Montana, Swenson et al. (1983) noted that 46% of white-tailed deer were observed wintering on upland prairie where little cover was available for thermal protection. This behavior also was documented by Moen (1968), Sparrowe and Springer (1970), Kramer (1971), and Kucera (1976) in Minnesota, South Dakota, Alberta, and Manitoba, respectively. When high quality forage was not available, or was limited during winter, deer selected habitat relative to topographic relief to minimize exposure to wind (Wood 1988, Nixon et al. 1991).

Sparrowe and Springer (1970) reported winter deer herds consisting of 24-30 and 48-80 deer that used cattail marshes for bedding cover in South Dakota. Similarly, Kramlich (1985) reported herds of 40-60 deer bedded in or along the edges of wetlands in eastern South Dakota throughout the winter of 1983-84. However, little attention has been directed to quantifying use of emergent vegetation as a dominant source of cover for deer (Sparrowe and Springer 1970, Kramlich 1985).

In landscapes where emergent vegetation constitutes a large proportion of habitat, intense habitat use studies are necessary to document deer/habitat interactions to effectively manage populations. The purpose of this research was to evaluate white-tailed deer winter/spring habitat use on SLNWR and nearby private lands. Specific objectives were: 1) to rank habitat preference at the landscape level, 2) to rank habitat preference at the home range level, 3) to compare habitat preference between the landscape and home range levels, and 4) to compare habitat preference and importance at the landscape and home range levels.

## METHODS

### Deer Trapping

To characterize white-tailed deer movement and habitat use over the entire refuge, SLNWR was divided into 6 color zones (Fig. 2). Each zone approximated 1,000-1,500 ha. Individual zones were divided along current road systems, dikes, and/or the James River. Private lands were zoned separately and consisted of lands outside refuge boundaries.

White-tailed deer were captured with modified Clover traps (Clover 1956) baited with shelled corn and salt during summer (1 July to 30 September) 1992 and 1993 and

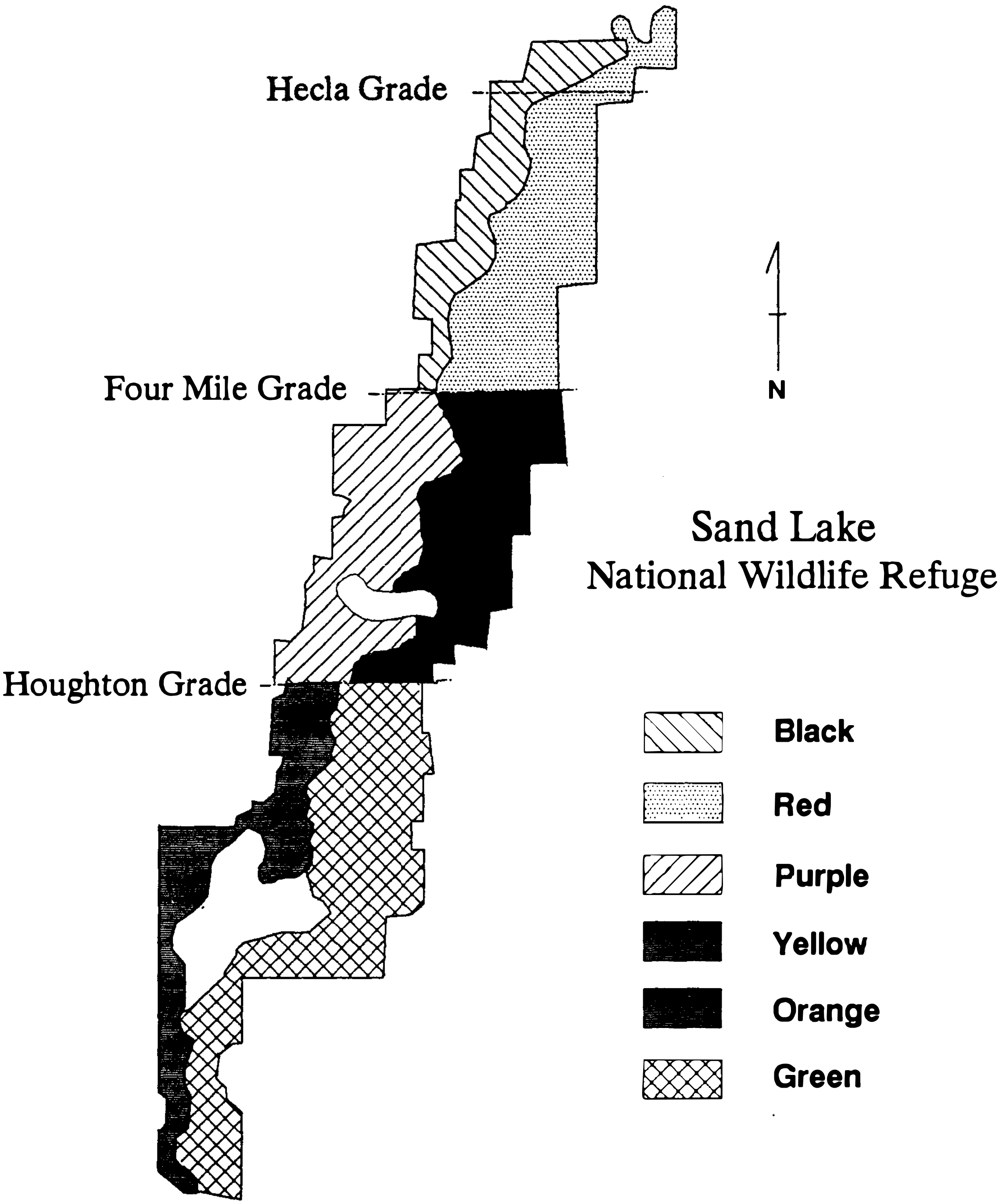

Figure 2. Color zones for white-tailed deer trapping and monitoring on Sand Lake National Wildlife Refuge.

winter (1 January to 31 March) 1993 and 1994 (Naugle et al. 1994b). Forty-five trap sites were selected based on accessibility, observation of deer activity, and location with respect to other trap sites. Traps sites were distributed evenly throughout each color zone (Fig. 2) to ensure equal representation of deer throughout SLNWR. Ten traps per season were set and monitored daily.

Captured deer were manually restrained and marked with metal and plastic ear-tags. Plastic ear-tags were color coded according to the color zone in which the deer was trapped. Captured deer were aged using tooth replacement and wear techniques (Severinghaus 1949, Severinghaus and Cheatum 1956) and weight estimated from chest/girth measurements (Weckerly et al. 1987) and hind foot lengths (Roseberry and Klimstra 1975). Selected adult (≥ 2.5-year-old) and yearling (1.5-year-old) deer were fitted with radio collars (Telonics, Inc., Mesa, Arizona) depending on sex, age, and location of capture. Radio collars were fitted with mercury-tip switches oriented to indicate head up/head down position to assess activity of monitored deer (Beier and McCullough 1988, Lariviere 1994).

**Deer Monitoring**

White-tailed deer were monitored from 6 January to 28 June 1993 and 13 January to 27 June 1994. Azimuths were estimated using a vehicle-mounted null antenna system fitted with an integrated azimuth locating device (Hallburg et al.

1974, Balkenbush and Hallett 1988) and a Telonics TR-2 scanner/receiver (Telonics, Inc., Mesa, Arizona). Extreme weather conditions during winter 1994 precluded exclusive use of the vehicle mounted system between 13 January and 17 March. During this period azimuths were estimated using a 4-element directional antenna mounted on a tripod and a hand-held compass (Silva, Inc., Sweden)

Deer locations were estimated by triangulation from 2 to 5 known receiver locations (e.g., road intersections) using XYLOG (Dodge and Steiner 1986). Locations of deer were obtained within 20 minutes. Azimuths collected after 20 minutes were not included in analyses. Mean 95% confidence ellipse and mean distance to signal source for seasonal locations were calculated using XYLOG.

Accuracy of both telemetry systems was determined at a distance of 866 m by placing a transmitter at locations unknown to the observer. Ten independent azimuths were taken while blindfolded. This procedure was repeated 3 times per observer. The standard deviation of the error angle for the vehicle-mounted system and the hand-held system was 0.7 and 3.5 degrees, respectively.

Independence between locations was determined by monitoring 3 deer each season for 48 hours. Cumulative distances between locations during the 48 hour session were examined for autocorrelation to determine time of independence (Swihart and Slade 1985). Individual deer were monitored every 20 hours, which ensured independence of observations obtained. To distribute locations over the entire day, deer were monitored in sequential order and start time lagged daily until monitoring had begun with each hour of the day.

**Habitat Coverage**

Upland habitat coverages were digitized using PC ARC/INFO (Environmental System Research Institute, Inc., (ESRI), Redlands, Calif.), a geographic information system (GIS) from 1:8,000 scale black and white aerial photographs that were ground truthed to ensure accuracy. Minimum root mean square (RMS) error was set at 0.03 (ESRI 1991a). A wetland habitat coverage was obtained as a digital coverage (USDI Bureau of Reclamation, Bismarck, ND) and combined with the upland habitat coverage using a GIS. Ten habitats were identified; alfalfa, brome-dominated (Bromus inermis) grasslands, corn, dense-cover grasslands (e.g., big bluestem [Andropogan gerardii], intermediate wheatgrass [Andropogan intermedium], clover [Trifolium spp.]), emergent vegetation, open water, row crops other than corn (e.g., soybeans), small grain (e.g., wheat), treebelts, and other (i.e., residential, transportation routes, unidentified). Habitat coverages were updated each spring following planting of new crops. Habitat patch size on SLNWR was calculated for each season.

## Home Range Generation

Ninety-five and 50% home range contours were calculated for each deer per season using an adaptive kernel method (Worton 1989) contained within Program CALHOME (U.S. Forest Service, Pacific Southwest Research Station and California Dep. Fish and Game, Calif.). In this study, the 50% home range contour was considered the core area of the home range (Dixon and Chapman 1980).

Home range contours, including core area, were identified on a habitat coverage of SLNWR and surrounding private lands using a GIS. Identity procedures were used to compute the geometric intersection of home range contour coverages and habitat coverages and combine feature attributes (e.g., area, habitat) of both coverages (ESRI 1991b) (Fig. 3).

## Habitat Use and Availability

Habitat use and availability were calculated at 2 levels (Johnson 1980): landscape (Level 2) and home range (Level 3). Individual deer were considered the sample unit. Level 2 was considered habitat use at the landscape scale, while Level 3 was considered habitat use at the home range scale (Johnson 1980). Level 2 habitat use was calculated as the proportional area by habitat within the 95% home range contour. Level 2 availability was calculated as proportional area by habitat within the boundaries of SLNWR. Level 3 habitat use was calculated as the

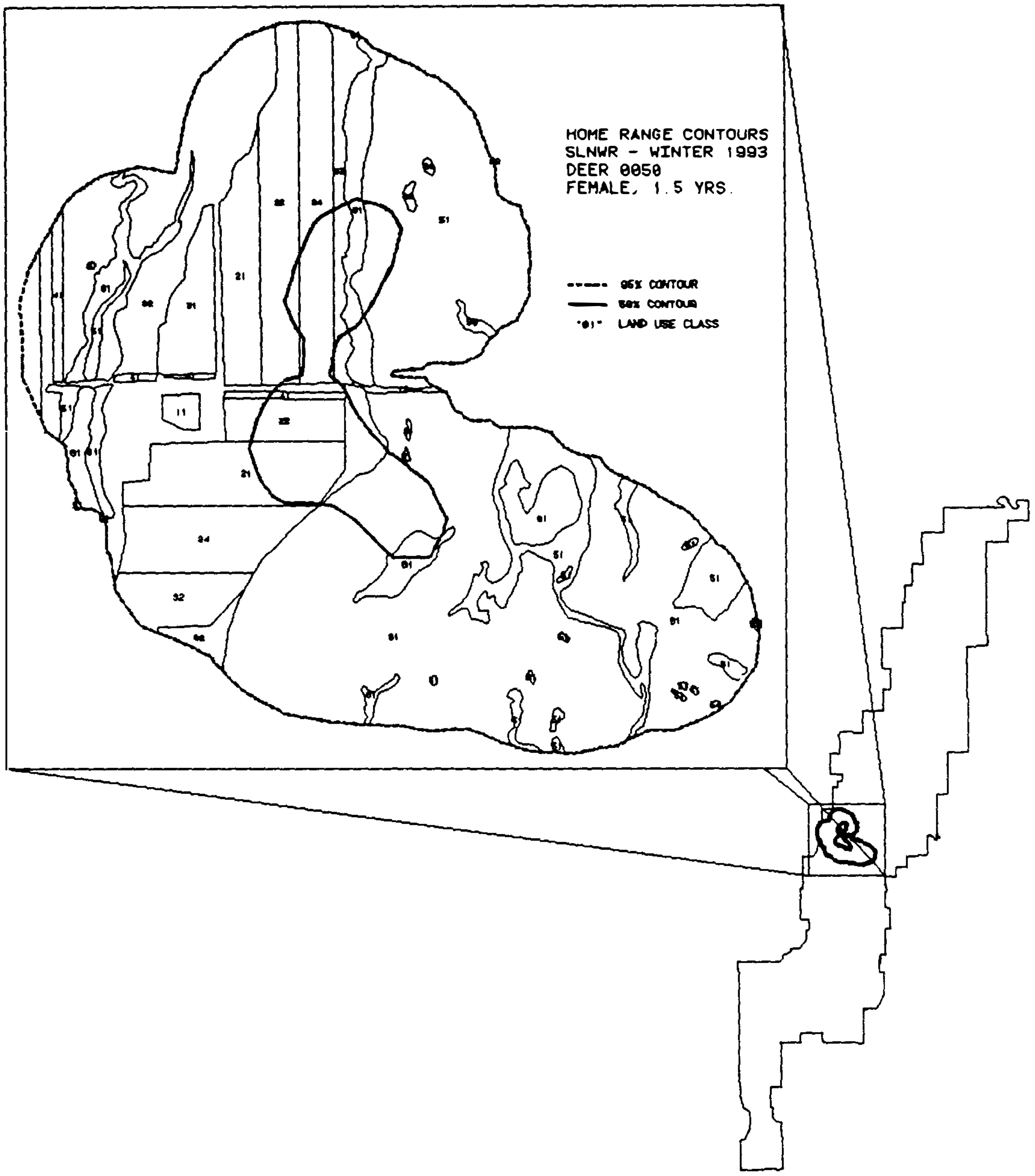

Figure 3. GIS coverage of a white-tailed deer home range identified on Sand Lake National Wildlife Refuge habitat coverage. Habitats (land use class) are: 21) corn, 22) small grain, 23) row crop other than corn, 24) alfalfa, 31) dense-cover grassland, 32) brome-dominated grassland, 41) treebelt, 51) water, 61) emergent vegetation, 99) other habitats.

proportional area by habitat within the core area. Level 3 availability was calculated as the proportional area by habitat within the 95% home range.

## Analytical Methods

Multivariate analysis of variance (MANOVA) applied to ranked data (Friedman 1937, Conover and Iman 1981, Sokal and Rohlf 1981) was used to test for between-group differences by reference to within-group between-animal variation of use data (Aebischer et al. 1993) within Levels 2 and 3.

Seasonal habitat preference was assessed according to Johnson (1980) using Program PREFER (Frank and Kopas 1985) at both levels (i.e., Levels 2 and 3), where preference was defined as a measure of the likelihood of a habitat being chosen (Petrides 1975, Porter and Church 1987, White and Garrott 1990). Waller-Duncan multiple comparison procedures were used to make paired comparisons between calculated ranks (Waller and Duncan 1969, Frank and Kopas 1985). Seasonal habitat importance was indexed according to proportional area used (Petrides 1975). Analysis of variance (ANOVA) was used to test for variation within preference and importance ranks at both levels (Sokal and Rohlf 1981). A Wilcoxon matched-pairs signed-ranks test was used to compare preference and importance ranks by habitat at both levels (Daniel 1990). MANOVA and ANOVA tests were considered significant at $P \leq 0.05$; whereas, the Wilcoxon matched-pairs signed-ranks tests were considered significant at $P \leq 0.10$.

## RESULTS

### Radio-telemetry and Habitat Coverage Accuracy

Twenty-four radio-collared deer (7 males, 17 females) were monitored during winter (6 January to 31 March) and spring (2 April to 28 June) 1993 resulting in 1,342 and 1,151 relocations, respectively. Fifteen radio-collared deer (4 males, 11 females) were monitored during winter (13 January to 31 March) 1994; whereas, 18 radio-collard deer were monitored during spring (3 April to 27 June) 1994 resulting in 722 and 843 locations, respectively.

Mean 95% confidence ellipse was 0.0014 ha (SE = 0.002, Range = 0.00-0.12, $n$ = 1,342) for winter 1993, 0.0015 ha (SE = 0.002, Range = 0.00-0.07, $n$ = 1,151) for spring 1993, 0.0080 ha (SE = 0.0009, Range = 0.00-0.30, $n$ = 722) for winter 1994, and 0.0009 ha (SE = 0.00017, Range = 0.00-0.09, $n$ = 843) for spring 1994. Mean distance to signal source was 1,005 m (SE = 11.9, Range = 248-3,380, $n$ = 1,212) for winter 1993, 992 m (SE = 12.5, Range = 231-3,356, $n$ = 1,042) for spring 1993, 1,250 m (SE = 23.6, Range = 134-3,927, $n$ = 619) for winter 1994, and 949 m (SE = 14.7, Range = 249-3,012, $n$ = 696) for spring 1994.

Mean habitat patch size on SLNWR calculated from the winter 1993 habitat coverage was 8.9 ha (SE = 1.9, Range =

0.005-1,214, _n_ = 955). Mean habitat patch size calculated from the spring 1993/winter 1994 habitat coverage also was 8.9 ha (SE = 1.9, Range = 0.001-1,214, _n_ = 961), whereas mean habitat patch size calculated from the spring 1994 habitat coverage was 9.0 ha (SE = 1.9, Range = 0.001-1,214, _n_ = 968).

## Habitat Preference and Importance

A sex by age by season interaction ($\lambda = 0.730$, df = 10,56, _P_ = 0.043) occurred for percent habitat use at the landscape level. Likewise, a 2-factor interaction ($\lambda = 0.629$, df = 10,56, _P_ = 0.002) occurred between season and year. At the home range level, a 4-factor interaction occurred between sex, age, season, and year ($\lambda = 0.689$, df = 10,56, _P_ = 0.014). Because significant interactions between sex, age, season, and year existed at both levels of analyses, data were not pooled across seasons or years in preference analyses. However, due to low sample size, data were pooled across sex and age.

### Landscape Level

In winter 1993, small grain, row crops other than corn, and alfalfa habitats were most preferred over dense-cover grasslands, corn, and water at the landscape level (Table 1; Fig. 4). Similarly, small grain and alfalfa were preferred in winter 1994; however, corn was preferred over all other habitats (Table 1; Fig. 4). Additionally, in winter 1994

Table 1. Mean seasonal use (%) and availability (%) of 10 habitats for white-tailed deer at Sand Lake National Wildlife Refuge, South Dakota, at the landscape level, 1993-1994.

| | Winter 1993 (n = 24) | | Spring 1993 (n = 24) | | Winter 1994 (n = 15) | | Spring 1994 (n = 18) | |
|---|---|---|---|---|---|---|---|---|
| Habitat[a] | Use | Avail. | Use | Avail. | Use | Avail. | Use | Avail. |
| CR | 6.36 | 3.16 | 10.42 | 2.88 | 11.46 | 2.88 | 16.42 | 3.12 |
| SG | 6.44 | 2.74 | 11.21 | 3.20 | 14.21 | 3.20 | 12.77 | 3.38 |
| RC | 3.09 | 0.52 | 1.43 | 0.06 | 0.69 | 0.06 | 5.49 | 0.36 |
| AF | 6.41 | 2.79 | 8.01 | 3.12 | 7.56 | 3.12 | 5.77 | 2.30 |
| DC | 1.64 | 2.93 | 5.45 | 2.93 | 4.86 | 2.93 | 4.47 | 3.31 |
| BR | 22.22 | 23.55 | 25.21 | 23.40 | 26.16 | 23.40 | 26.56 | 23.99 |
| TR | 1.64 | 1.94 | 4.05 | 1.94 | 4.02 | 1.94 | 5.34 | 1.93 |
| WT | 15.75 | 28.39 | 9.81 | 28.39 | 8.65 | 28.39 | 8.54 | 28.09 |
| EM | 35.15 | 33.09 | 20.58 | 33.11 | 19.61 | 33.11 | 12.34 | 32.33 |
| OT | 1.29 | 0.89 | 3.82 | 0.97 | 2.78 | 0.97 | 2.29 | 1.19 |
| Total | 99.99 | 100.00 | 99.99 | 100.00 | 100.00 | 100.00 | 99.99 | 100.00 |

[a] Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grasslands, BR) brome-dominated grasslands, TR) treebelts, WT) water, EM) emergent vegetation, OT) other (i.e., residential, transportation routes, unidentified).

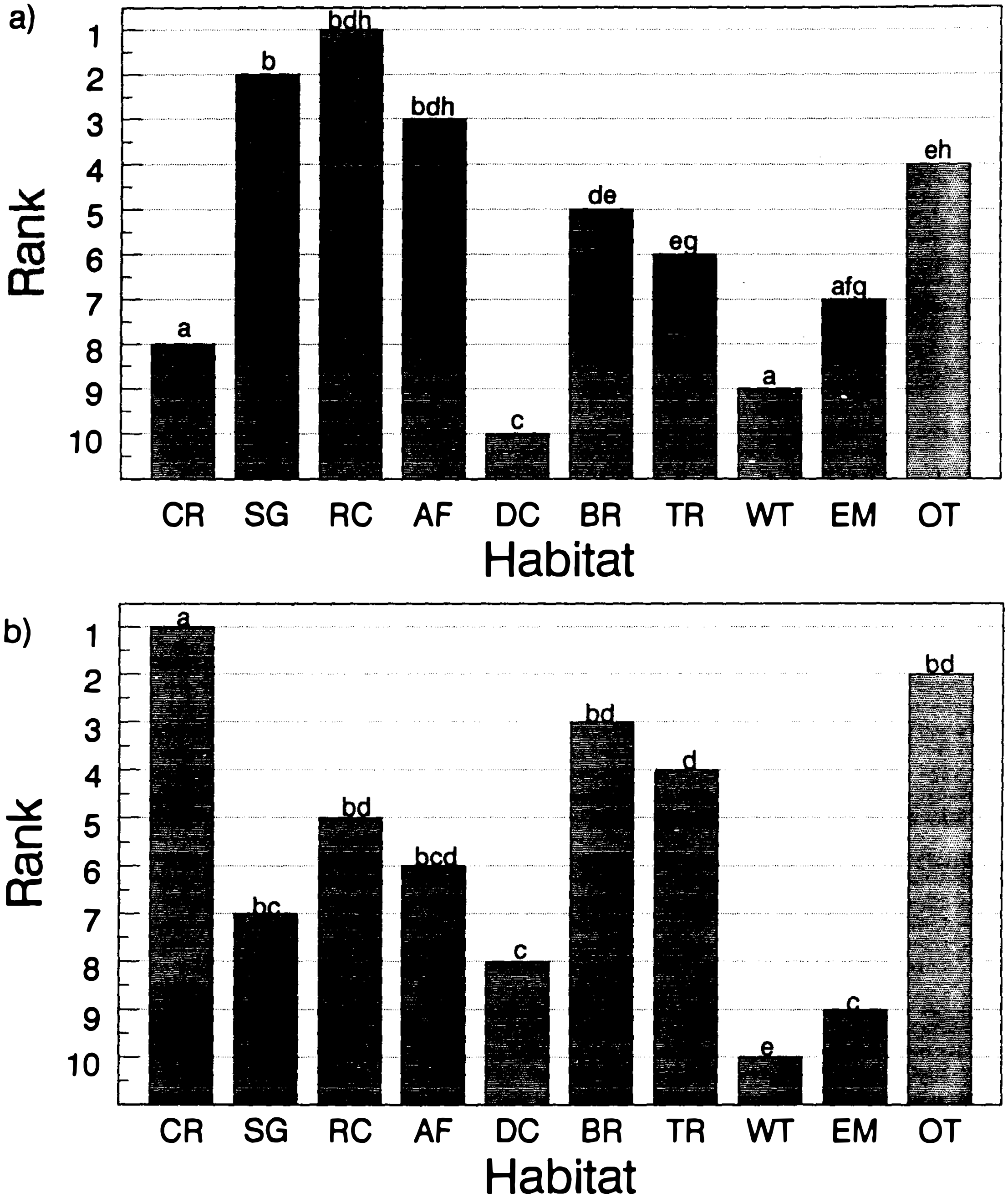

Figure 4. White-tailed deer landscape level habitat preference rankings on Sand Lake National Wildlife Refuge for winter: a) 1993 and b) 1994. Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelt, WT) water, EM) emergent vegetation, and OT) other habitats. Habitats with the same letter represent no difference (P > 0.05).

brome-dominated grasslands and treebelts were preferred habitats (Table 1; Fig. 4).

In spring 1993, corn was most preferred; however, row crops other than corn, brome-dominated grasslands, dense-cover grasslands, and other habitats also were preferred (Fig. 5). Water and emergent vegetation were among the least preferred habitats in spring 1993 (Fig. 5). Corn and row crops other than corn were most preferred during spring 1994 (Table 1; Fig. 5); whereas, water and emergent vegetation were least preferred (Fig. 5).

### Home Range Level

Treebelts and other habitats were most preferred at the home range level in winter 1993; whereas, corn, row crops other than corn, and water were least preferred (Table 2; Fig. 6). Winter 1994 resulted in all habitats except for brome-dominated grasslands, water, and emergent vegetation being equally preferred (Table 2; Fig. 6). Treebelts, row crops other than corn, alfalfa, and other habitats were among the highest preferred habitats at the home range level in spring 1993 and 1994 (Table 2; Fig. 7). Corn, small grain, and water were least preferred at the home range level in spring 1993 and 1994 (Fig. 7).

### Landscape/Home Range Comparison

Treebelts were more preferred at the home range level in winter when compared to the landscape level (Table 2; Fig. 6). Preference towards dense-cover grasslands at the

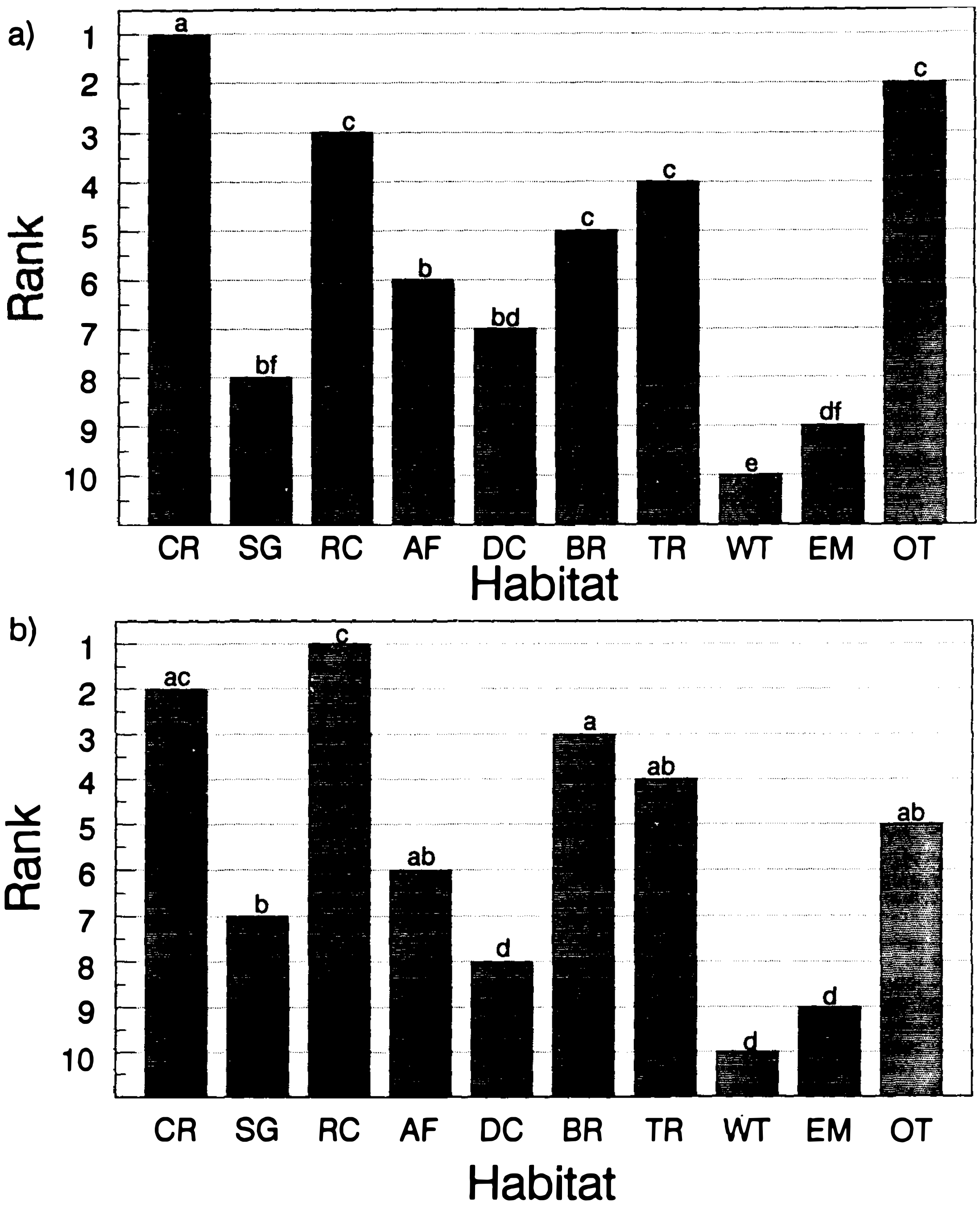

Figure 5. White-tailed deer landscape level habitat preference rankings on Sand Lake National Wildlife Refuge for spring: a) 1993 and b) 1994. Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelt, WT) water, EM) emergent vegetation, and OT) other habitats. Habitats with the same letter represent no difference (P > 0.05).

Table 2. Mean seasonal use (%) and availability (%) of 10 habitats for white-tailed deer at Sand Lake National Wildlife Refuge, South Dakota, at the home range level, 1993-1994.

| | Winter 1993 (n = 24) | | Spring 1993 (n = 24) | | Winter 1994 (n = 15) | | Spring 1994 (n = 18) | |
|---|---|---|---|---|---|---|---|---|
| Habitat[a] | Use | Avail. | Use | Avail. | Use | Avail. | Use | Avail. |
| CR | 2.30 | 6.36 | 5.95 | 10.42 | 12.22 | 11.46 | 16.54 | 16.42 |
| SG | 4.69 | 6.44 | 8.54 | 11.21 | 13.22 | 14.21 | 12.19 | 12.77 |
| RC | 0.63 | 3.09 | 1.00 | 1.43 | 0.14 | 0.69 | 2.06 | 5.49 |
| AF | 7.52 | 6.41 | 9.73 | 8.01 | 11.94 | 7.56 | 7.71 | 5.77 |
| DC | 0.74 | 1.64 | 6.66 | 5.45 | 5.79 | 4.86 | 5.28 | 4.47 |
| BR | 30.84 | 22.22 | 26.93 | 25.21 | 26.84 | 26.16 | 27.90 | 26.56 |
| TR | 1.51 | 1.64 | 4.71 | 4.05 | 7.21 | 4.02 | 9.08 | 5.34 |
| WT | 10.05 | 15.75 | 6.67 | 9.81 | 2.19 | 8.65 | 4.87 | 8.54 |
| EM | 41.02 | 35.15 | 27.23 | 20.58 | 19.47 | 19.61 | 11.28 | 12.34 |
| OT | 0.69 | 1.29 | 2.59 | 3.82 | 0.98 | 2.78 | 3.10 | 2.29 |
| Total | 99.99 | 99.99 | 100.01 | 99.99 | 100.00 | 100.00 | 100.01 | 99.99 |

[a] Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grasslands, BR) brome-dominated grasslands, TR) treebelts, WT) water, EM) emergent vegetation, OT) other (i.e., residential, transportation routes, unidentified).

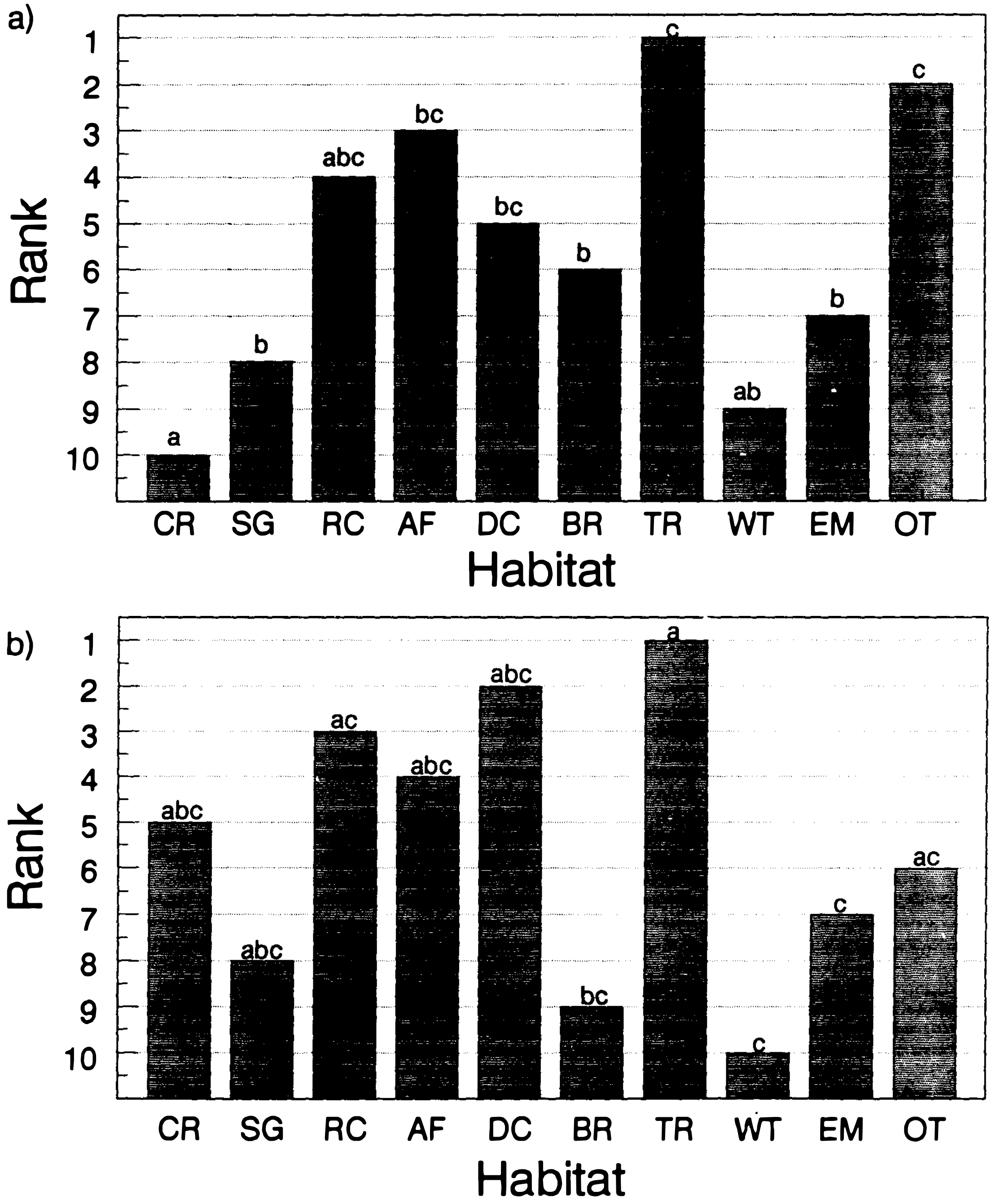

Figure 6. White-tailed deer home range level habitat preference rankings on Sand Lake National Wildlife Refuge for winter: a) 1993 and b) 1994. Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelt, WT) water, EM) emergent vegetation, and OT) other habitats. Habitats with the same letter represent no difference (P > 0.05).

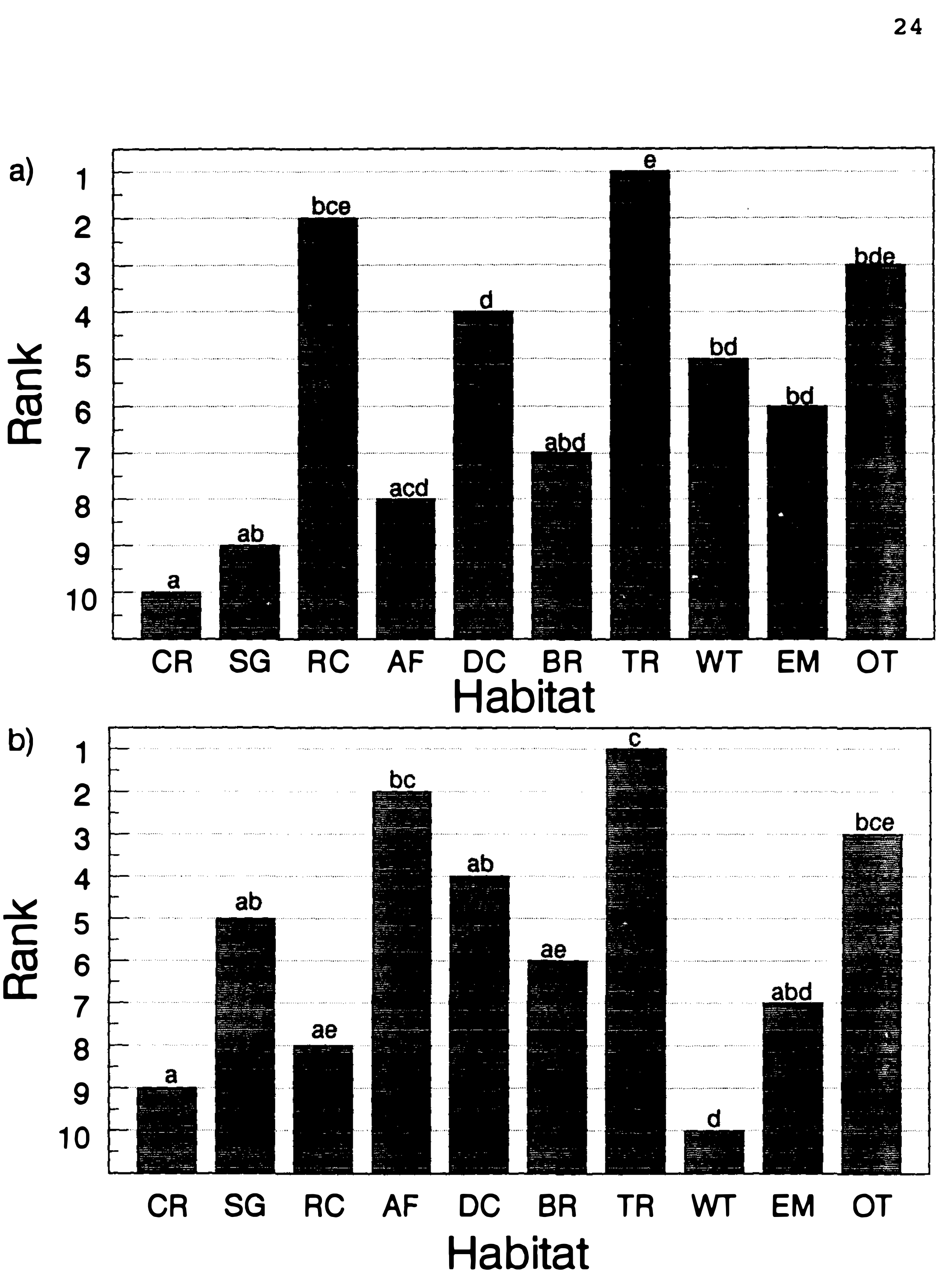

Figure 7. White-tailed deer home range level habitat preference rankings on Sand Lake National Wildlife Refuge for spring: a) 1993 and b) 1994. Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelt, WT) water, EM) emergent vegetation, and OT) other habitats. Habitats with the same letter represent no difference (P > 0.05).

home range level was greater than preference at the landscape level in winter (Fig. 6). Consistent with winter preference, treebelts and dense-cover grasslands were more preferred at the home range level than at the landscape level in spring (Table 2; Fig. 7). Emergent vegetation became more preferred at the home range level than at the landscape level during spring (Fig. 7).

### Preference/Importance Comparison

Although variability existed between proportional use (Table 1, 2), preference ranks (Table 3, 4) did not differ ($P > 0.05$) by season, year or habitat at both levels. Likewise, importance ranks (Table 3, 4) were similar with respect to season, year and habitat ($P > 0.05$) at both levels. Therefore, seasonal preference and importance ranks were pooled and compared.

At the landscape level, no differences between preference and importance were detected for agricultural crops and dense-cover grasslands ($P > 0.10$) except for row crops other than corn, where preference was greater than importance ($Z = -1.473$, $n = 4$, $P = 0.066$) (Fig. 8). Preference was greater than importance for treebelts ($Z = 1.890$, $n = 4$, $P = 0.059$) and other habitats ($Z = 1.841$, $n = 4$, $P = 0.066$) as well (Fig. 8). Brome-dominated grasslands, water, and emergent vegetation exhibited higher importance ranks than preference ranks (Fig. 8; BR [$Z = -1.841$, $n = 4$,

Table 3. Seasonal white-tailed deer habitat preference and importance ranks at Sand Lake National Wildlife Refuge, South Dakota, at the landscape level, 1993-1994.

| Habitat Type[a] | Winter 1993 (n = 24) | | Spring 1993 (n = 24) | | Winter 1994 (n = 15) | | Spring 1994 (n = 18) | |
|---|---|---|---|---|---|---|---|---|
| | Pref.[b] | Imp.[c] | Pref. | Imp. | Pref. | Imp. | Pref. | Imp. |
| CR | 8 | 6 | 1 | 4 | 1 | 4 | 2 | 2 |
| SG | 2 | 4 | 7 | 3 | 8 | 3 | 7 | 3 |
| RC | 1 | 7 | 5 | 10 | 3 | 10 | 1 | 7 |
| AF | 3 | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| DC | 10 | 8.5 | 8 | 7 | 7 | 7 | 8 | 9 |
| BR | 5 | 2 | 3 | | 5 | 1 | 3 | 1 |
| TR | 6 | 8.5 | 4 | 8 | 4 | 8 | 4 | 8 |
| WT | 9 | 3 | 10 | 5 | 10 | 5 | 10 | 5 |
| EM | 7 | 1 | 9 | 2 | 8 | 2 | 9 | 4 |
| OT | 4 | 10 | 2 | 9 | 2 | 9 | 5 | 10 |

[a] Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grasslands, BR) brome-dominated grasslands, TR) treebelts, WT) water, EM) emergent vegetation, OT) other (i.e., residential, transportation routes, unidentified).

[b] Pref.: Preference ranking (Johnson 1980).

[c] Imp.: Importance ranking (% use ranked).

Table 4. Seasonal white-tailed deer habitat preference and importance ranks at Sand Lake National Wildlife Refuge, South Dakota, at the home range level, 1993-1994.

| Habitat Type[a] | Winter 1993 (n = 24) | | Spring 1993 (n = 24) | | Winter 1994 (n = 15) | | Spring 1994 (n = 18) | |
|---|---|---|---|---|---|---|---|---|
| | Pref.[b] | Imp.[c] | Pref. | Imp. | Pref. | Imp. | Pref. | Imp. |
| CR | 10 | 6 | 5 | 7 | 10 | 4 | 9 | 2 |
| SG | 8 | 5 | 8 | 4 | 9 | 3 | 5 | 3 |
| RC | 4 | 10 | 3 | 10 | 2 | 10 | 8 | 10 |
| AF | 3 | 4 | 4 | 3 | 8 | 5 | 2 | 6 |
| DC | 5 | 8 | 2 | 6 | 4 | 7 | 4 | 7 |
| BR | 6 | 2 | 9 | 2 | 7 | 1 | 6 | 1 |
| TR | 1 | 7 | 1 | 8 | 1 | 6 | 1 | 5 |
| WT | 9 | 3 | 10 | 5 | 5 | 8 | 10 | 8 |
| EM | 7 | 1 | 7 | 1 | 6 | 2 | 7 | 4 |
| OT | 2 | 9 | 6 | 9 | 3 | 9 | 3 | 9 |

[a] Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grasslands, BR) brome-dominated grasslands, TR) treebelts, WT) water, EM) emergent vegetation, OT) other (i.e., residential, transportation routes, unidentified).

[b] Pref.: Preference ranking (Johnson 1980).

[c] Imp.: Importance ranking (% use ranked).

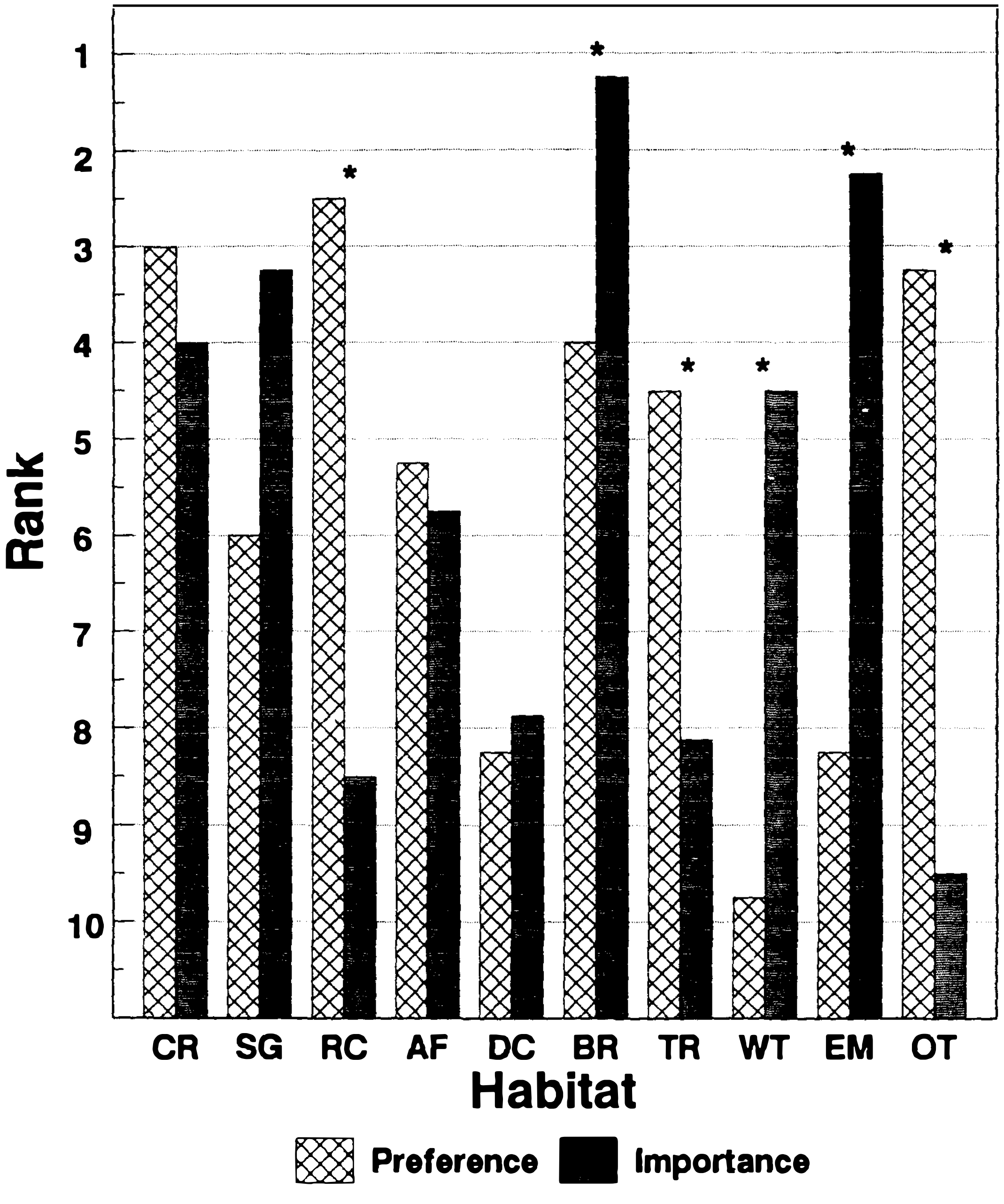

Figure 8. White-tailed deer habitat preference/importance comparison for seasons combined at Sand Lake National Wildlife Refuge at the landscape level. Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelt, WT) water, EM) emergent vegetation, and OT) other habitats. An * represents a significant difference between preference and importance ($P \leq 0.10$).

$P$ = 0.066], WT [$Z$ = -1.890, $n$ = 4, $P$ = 0.059], EM [$Z$ = -1.841, $n$ = 4, $P$ = 0.066]).

Comparison of preference and importance ranks at the home range level resulted in trends similar to those at the landscape level (Fig. 9). However, importance of small grain ranked significantly higher than preference ($Z$ = -1.826, $n$ = 4, $P$ = 0.068) of small grain, while dense-cover grasslands received a higher preference rank ($Z$ = 1.890, $n$ = 4, $P$ = 0.059) than importance rank (Fig. 9).

## DISCUSSION

Until recently, error in radio-telemetry systems has not been reported or minimized (Springer 1979, Lee et al. 1985, White and Garrott 1986, Samuel and Kenow 1992, Saltz 1994), which may result in misinterpretation of data and management recommendations (Saltz 1994). Use of a vehicle mounted antenna system allowed for increased accuracy in 95% confidence ellipse and mean distance to signal source. Furthermore, the use of a GIS enabled habitat coverages to accurately represent mean patch size as it was related to mean confidence ellipse and white-tailed deer habitat use.

Point location data traditionally has been used in habitat use analyses. White and Garrott (1990) disregarded the home range approach to estimating habitat utilization distributions given the lack of a perfect home range estimator. However, bias may result if telemetry error

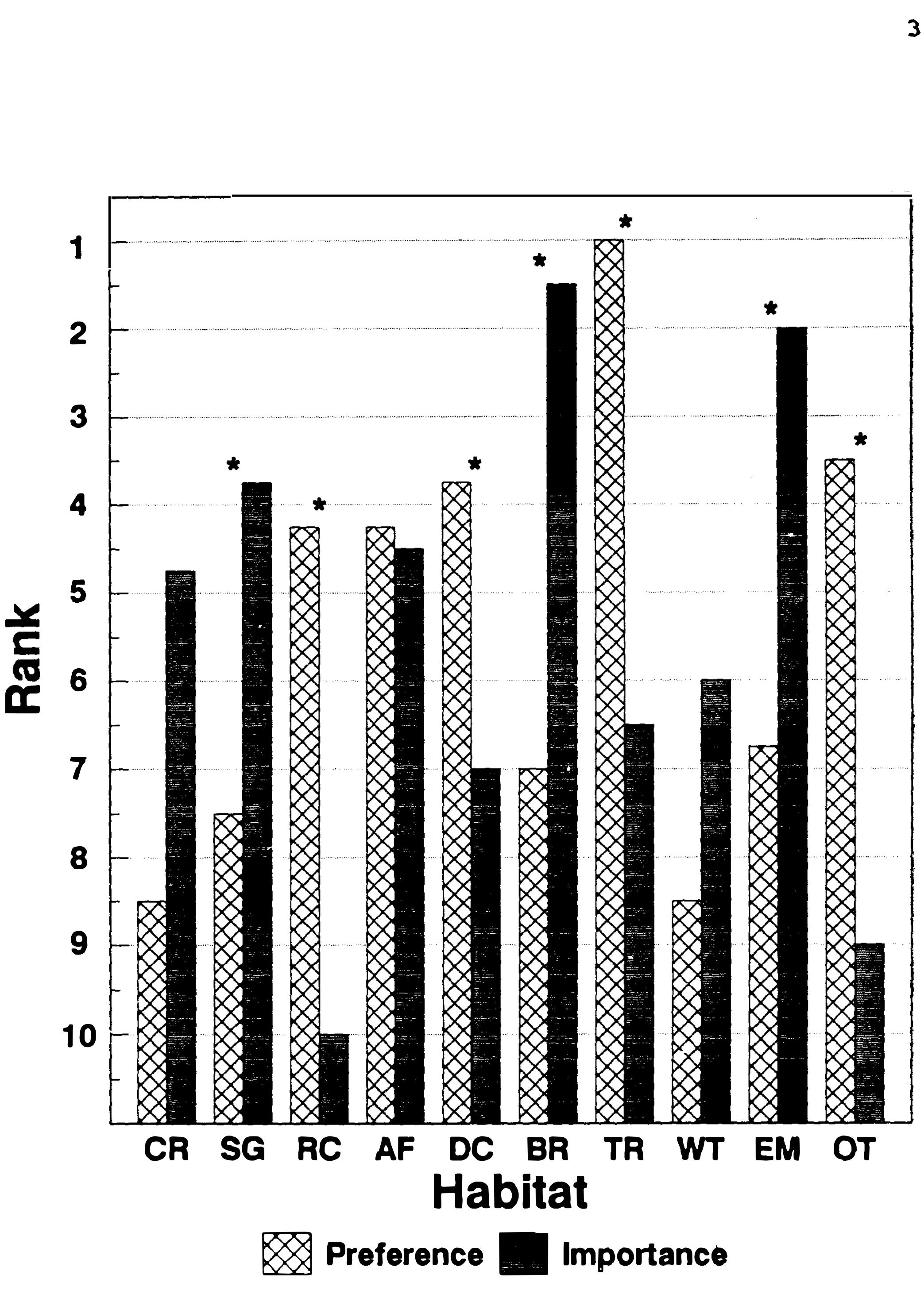

Figure 9. White-tailed deer habitat preference/importance comparison for seasons combined at Sand Lake National Wildlife Refuge at the home range level. Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelt, WT) water, EM) emergent vegetation, and OT) other habitats. An * represents a significant difference between preference and importance ($P < 0.10$).

associated with point location data is not considered when analyzing habitat use. The adaptive kernel method of home range construction provided a viable method of quantifying habitat use and addressed the potential bias associated with point location data by estimating the complete utilization distribution of the animal (Worton 1989). Furthermore, the adaptive kernel method of home range estimation is preferred over other estimators (e.g., minimum convex polygon, harmonic mean) because the utilization distribution estimate is free of parametric assumptions and provides a means of smoothing locational data (Worton 1989, Naef-Daenzer 1994).

## Winter Habitat Preference

Habitat preference in winter 1993 was consistent with other reports of white-tailed deer habitat use in the northern Great Plains (Swenson et al 1983, Dusek et al. 1988, Kennedy 1992). Agricultural lands were highly preferred except for corn. Although SLNWR does not contain traditional wooded riparian draws, emergent vegetation along the riparian corridor was not preferred over agricultural crops.

Habitat preference in winter 1994 was potentially influenced by extreme weather conditions. For example, 1993 and 1994 maximum snow depth was 58 and 112 cm, respectively; while mean minimum temperature was -15.7°C and -17.5°C in winter 1993 and 1994, respectively. Preference for agricultural crops decreased except for corn. Half of the corn on SLNWR remained standing throughout winter (J. Jave, pers. comm., U.S. Fish and Wildlife Service, SLNWR) and thus was available to deer even after considerable snowfall. Treebelts were more preferred in winter 1994 than 1993, which was consistent with reports of white-tailed deer use of such habitats when little food or cover was available elsewhere (Zwank et al. 1979, Murphy et al. 1985, Nixon et al. 1991, Gould and Jenkins 1993).

Moen (1968) noted that well-fed deer could tolerate cold stress with little cover. In winter 1994, preference of brome-dominated grasslands was high even though little cover was afforded. Such behavior has been documented in Minnesota (Moen 1968), South Dakota (Sparrowe and Springer 1970), Montana (Swenson et al. 1983), Alberta (Kramer 1971), and Manitoba (Kucera 1976). Snow does not accumulate in brome-dominated grasslands as it does in taller stands of vegetation in prairie landscapes. Therefore, preference for brome-dominated grasslands increased as other habitats became inaccessible.

One notable difference at the home range level, when compared to the landscape level, was the increased preference for treebelts in winter. Habitat use at the home range level represented the animal's core area of use and suggested use of wooded areas for cover and food when agricultural crops were limited (Zwank et al. 1979, Murphy et al. 1985, Nixon et al. 1991, Gould and Jenkins 1993).

Wooded areas also were preferred when in close proximity to agricultural fields, thus providing adequate juxtaposition of high quality forage and cover (Swenson et al. 1983, Compton et al. 1988, Dusek et al. 1988, Parker and Gillingham 1990).

### Spring Habitat Preference

Habitat preference at the landscape level in spring was consistent with other studies in the region (Zwank et al. 1979, Murphy et al. 1985, Kennedy 1992). Agricultural lands, especially corn and row crops other than corn, were highly preferred. Use of corn and soybeans in initial stages of development by white-tailed deer has been reported by Kramlich (1985) and Nixon et al. (1991). Agricultural crops on SLNWR offer high quality forage to white-tailed deer in limited quantities and are therefore preferred over other habitats. In Montana, where croplands occupied approximately half of the study area, Dusek et al. (1988) reported less than expected use of croplands and use of riparian draws (7% available) at levels exceeding availability.

Use of grasslands in spring increased from winter. Grasslands provided undisturbed fawning habitat, which is critical to neonatal survival (Ozoga et al. 1982, Murphy et al. 1985, Gould and Jenkins 1993). Immature grasses also are generally high in protein and digestible energy (Verme and Ozoga 1980, Gould and Jenkins 1993) and thus, represented high quality forage for reproductively active females.

Consistent with home range level winter use, treebelts were unequivocally the most preferred habitat in spring at the home range level. Use of wooded areas is common in spring (Zwank et al. 1979, Murphy et al. 1985, Gould and Jenkins 1993); however, few studies report such strong preference when grasslands and agricultural crops are maturing. Home range level analyses represent habitat use patterns within core areas. Treebelts may represent centers of activity, especially for female deer, by serving as cover adjacent to forage (e.g., agricultural crops).

### Habitat Importance

Habitats that are most preferred are not necessarily those that are the most important (Maitland 1965, Petrides 1975, Dusek et al. 1988). Treebelts and agricultural crops were generally preferred at both the landscape and home range level; however, these habitats were not used in the greatest proportions.

The importance of habitats such as emergent vegetation and brome-dominated grasslands may be overshadowed by the low availability of agricultural lands and treebelts, resulting in inflated preference ranks for these habitats. For example, in winter 1993 row crops other than corn were preferred over all other habitats; however, emergent vegetation was considered the most important habitat.

Emergent vegetation serves as a dominate source of cover in winter (Sparrowe and Springer 1970, Kramlich 1985) as well as for bedding sites in spring. Even in winter 1994, when emergent vegetation was less available due to increased snow depth, emergent vegetation was ranked 2 in importance (a decrease of 1 rank from winter 1993). Therefore, even in extreme weather conditions, those habitats which were important to white-tailed deer continued to be used. Adequate juxtaposition of thermal cover (e.g., emergent vegetation) and highly nutritious forage (e.g., agricultural crops) is important to winter survival and maintenance of high density populations (Sparrowe and Springer 1970, Swenson et al. 1983, Compton et al. 1988, Dusek et al. 1988).

Brome-dominated grasslands may provide excellent fawning habitat as well as a source of food in early spring "green-up", thus contributing to such high importance rankings in both spring seasons. Brome-dominated grasslands serve as primary habitat for white-tailed deer when emergent vegetation is inundated in spring.

## MANAGEMENT IMPLICATIONS

Due to low availability of agricultural crops, especially row crops other than corn (e.g., soybeans) and treebelts on SLNWR, these habitats were frequently identified as preferred habitats for white-tailed deer considering that preference analyses are dictated by availability of habitat. Increased conservation of standing winter crops would undoubtedly restrict deer movement off SLNWR and decrease depredation complaints. In severe winters, such as winter 1994, treebelts served as a supplemental source of cover to resident animals when emergent vegetation was inaccessible.

Observed patterns of habitat use (i.e., importance) indicated that emergent vegetation and brome-dominated grasslands were crucial habitats to white-tailed deer on SLNWR. Large expanses of emergent vegetation on SLNWR serve as dominant wintering areas for resident (i.e., refuge) deer and deer that migrate to SLNWR (B. J. Kernohan, unpubl. data). Brome-dominated grasslands interspersed with dense-cover grasslands may provide suitable fawning habitat as well as high quality forage. Management strategies relating to preferred habitats alone neglect the importance of habitats such as emergent vegetation and brome-dominated grasslands in white-tailed deer management.

# Chapter 3: COVER CHARACTERISTICS OF CORN

In agricultural environments, corn can provide one of the primary habitats available to white-tailed deer (Korschgen 1962, Mustard and Wright 1965, Watt et al. 1967, Pils et al. 1981, Kramlich 1985, Nixon et al. 1991). Kramlich (1985) reported that corn was the most heavily used crop when available in eastern South Dakota. Nixon et al. (1991) reported deer feeding on maturing corn throughout late summer in Illinois.

Corn not only serves as forage but cover as well. Kramlich (1985) reported use of corn beginning in June, as soon as the plants were tall enough to provide cover in eastern South Dakota, and continuing until fields were harvested in fall. Dusek et al. (1988) reported increased diurnal use of cropland in winter and suggested that deer traveled from sheltered bedding sites to less sheltered areas to feed.

Temporal changes in forage and cover characteristics of corn may be important relative to deer use of corn. The purpose of this research was to evaluate cover characteristics of corn with respect to white-tailed deer use of corn. Specific objectives were: 1) to quantify cover characteristics of corn in terms of height and density, 2) to compare cover characteristics and deer use of corn, and

3) to evaluate deer use of corn fields with respect to activity of deer.

## METHODS

### Cover Characteristics

Fifteen corn fields were systematically located on SLNWR to achieve equal distribution of fields across SLNWR. Within each field, 5, 2 $m^2$ random plots were located and permanently marked as replicates. Mean planting date was 17 May 1993. Following initial "green-up" (i.e., 40 days of initial growth), plants were measured within 1 week blocks until maturity. Cover characteristics (i.e., height and density) were measured from 28 June to 14 August 1993.

Corn height was calculated to the nearest centimeter within each plot by averaging corn height of all plants within the plot. A 2.5 m vegetation profile board with 5, 0.5 m intervals was used to quantify density of corn at each plot (Nudds 1977). The board was placed at the southwest corner of the plot and read from a distance of 15 m to the northeast. The proportion of each 0.5 m interval covered by corn was recorded as a single digit density score, which corresponded to the mean value of a range of quintiles (Nudds 1977) (Table 5). Corn density per block was calculated as the mean score of all 5 intervals. Measurement of cover characteristics was terminated when

Table 5. Range of quintiles associated with single digit density scores measured with a vegetation profile board (Nudds 1977).

| Single Density Score | Mean Density Range | Percent Coverage |
|---|---|---|
| 1 | 0 - 1 | 0 - 20 |
| 2 | >1 - 2 | 21 - 40 |
| 3 | >2 - 3 | 41 - 60 |
| 4 | >3 - 4 | 61 - 80 |
| 5 | >4 - 5 | 81 - 100 |

≥ 50% of a corn field had reached mature height (i.e., corn silk appeared on plants) (Cross 1991).

**Deer Use and Activity**

White-tailed deer use of corn fields was monitored by relocating radio-collared deer from 17 May to 26 August 1993 as described in Chapter 1. Activity of individual deer was assessed by listening to amplitude and pulse interval of each telemetric signal for 5.25 min. (Beier and McCullough 1988, Lariviere 1994). A telemetric pattern of constant signal amplitude and head-up pulse interval for 100% of the trace indicated an inactive deer (e.g., bedded) (Beier and McCullough 1988). All other telemetric patterns indicated active deer (e.g., feeding).

**Analytical Methods**

Deer use of corn fields was calculated as percent relocations within buffered corn fields on SLNWR within 1 week blocks (i.e., Block 1, 17 May - 27 June; Block 2, 28 June - 4 July; Block 3, 5 - 11 July; Block 4, 12 - 18 July; Block 5, 19 - 25 July; Block 6, 26 July - 1 August; Block 7, 2 - 8 August; Block 8, 9 - 15 August) that corresponded to cover measurements. Cover characteristics in Block 1 were not measured. Corn fields were buffered (ESRI 1991b) inside of the field 1.5 m (i.e., mean radius of the calculated 95% confidence ellipse of telemetry locations) using a GIS to account for point location error. Activity was calculated as percent active deer and percent inactive deer in weekly blocks.

Analysis of variance applied to ranked data (Friedman 1937, Conover and Iman 1981, Sokal and Rohlf 1981) was used to assess variation between fields within weekly blocks. Nonlinear modeling (Steel and Torrie 1980) was used to model corn height, density, and use with respect to weekly blocks. Height, density, and use data were log transformed and Hollander's test for parallelism between slopes (Daniel 1990) was used to test whether the slopes of the regression lines describing the linear relationship between height and use were the same. Similarly, Hollander's test for parallelism (Daniel 1990) was used to test for homogeneity between slopes of the regression lines describing density and use. Analysis of variance and Hollander's tests were considered significant at $P \leq 0.05$.

## RESULTS

Analysis of variance resulted in significant differences between fields for both height ($\underline{P} < 0.001$) and density ($\underline{P} < 0.005$) in all blocks except for Block 1 for which no cover characteristics were measured. Although variability existed between fields, a quadratic relationship ($\underline{r}^2 = 0.998$, $\underline{n} = 7$; $Y = 6.5 * 0.3^X$) did exist between block

Table 6. Percent corn use by white-tailed deer, corn height, and corn density estimates for weekly blocks on Sand Lake National Wildlife Refuge, South Dakota in spring/summer 1993.

| Block[a] | Locations Refuge[b] | Locations Inside[c] | % Corn Use | Height (cm) (n=75) | Density[e] (n=75) |
|---|---|---|---|---|---|
| 1 | 324 | 6 | 1.85 | .[d] | . |
| 2 | 35 | 0 | 0.00 | 27.53 | 1.04 |
| 3 | 59 | 0 | 0.00 | 35.69 | 1.15 |
| 4 | 34 | 3 | 8.82 | 49.91 | 1.47 |
| 5 | 80 | 1 | 1.25 | 66.90 | 1.84 |
| 6 | 40 | 4 | 10.00 | 88.77 | 2.14 |
| 7 | 34 | 3 | 8.82 | 117.53 | 2.60 |
| 8 | 33 | 9 | 27.27 | 149.02 | 3.03 |

[a] Blocks are: 1) 17 May - 27 June, 2) 28 June - 4 July, 3) 5 - 11 July, 4) 12 - 18 July, 5) 19 - 25 July, 6) 26 July - 1 August, 7) 2 - 8 August, 8) 9 - 15 August.

[b] Number of locations which fall within refuge boundaries.

[c] Number of locations which fall within buffered corn fields (represents % corn use sample size [n]).

[d] . represents no data.

[e] Density scores corresponding to Nudds (1977) are: 0-1) 0 - 20%, >1-2) 21 - 40%, >2-3) 41 - 60%, >3-4) 61-80%, >4-5) 81 - 100%.

and corn height (Table 6). Similarly, a quadratic relationship ($\underline{r}^2 = 0.996$, $\underline{n} = 7$; $Y = 0.7 * 0.2^X$) existed between block and corn density, as well as between block and percent use of corn ($\underline{r}^2 = 0.841$, $\underline{n} = 7$; $Y = 0.1 * 0.7^X$) (Table 6).

The slope of the line describing percent use did not differ ($\underline{T} = 3$, $\underline{n} = 4$, $\underline{P} > 0.1$) from the slope of the line describing corn height (i.e., following log transformation) (Fig. 10). However, the slope of the line describing percent use did differ ($\underline{T} = 0$, $\underline{n} = 4$, $\underline{P} < 0.05$) from the slope of the line describing corn density (Fig. 10).

Activity varied from 0% deer active to 100% deer active throughout the 5 months (Table 7; Fig 11). Activity was highest in Block 1 (i.e., 17 May - 27 June) and lowest from Blocks 2 - 5 (i.e., 28 June to 25 July) and Blocks 11 - 12 (i.e., 30 August to 12 September) (Table 7; Fig. 11). Percent use of corn peaked as corn matured (i.e., Block 8) and tended to stabilize between Blocks 9 - 14 (i.e, 9 August to 26 September) (Table 7; Fig. 11).

Use of corn and activity in corn by white-tailed deer on SLNWR was related to growth patterns of corn (Fig. 11). Activity in the "planting" phase (17 May - 4 July) was 100% active indicating that deer were likely feeding while in corn fields. As use began to increase in the "initial

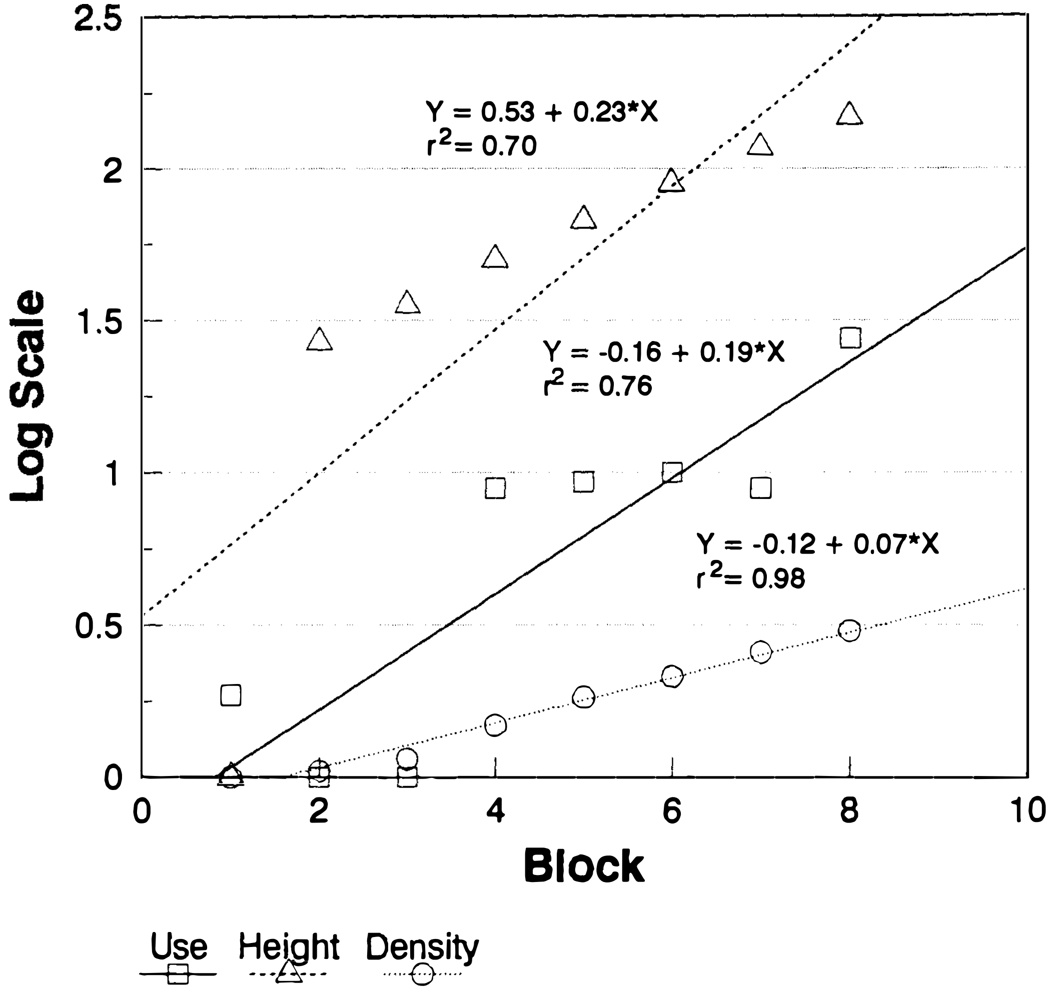

Figure 10. Linear relationships between white-tailed deer % use corn, corn height, and corn density at Sand Lake National Wildlife Refuge, spring/ summer 1993. Blocks are: 1) 17 May - 27 June, 2) 28 June - 4 July, 3) 5 - 11 July, 4) 12 - 18 July, 5) 19 - 25 July, 6) 26 July - 1 August, 7) 2 - 8 August, 8) 9 - 15 Auugust. Hollander's test for parallelism between use and height ($T = 3$, $n = 4$, $P > 0.10$) and use and density ($T = 0$, $n = 4$, $P < 0.03$).

Table 7. Percent corn use and percent activity of white-tailed deer in corn on Sand Lake National Wildlife Refuge, South Dakota, in spring/summer 1993.

| | Corn Use | | % Activity | | |
|---|---|---|---|---|---|
| Block[a] | n | Use (%) | n | Active | Inactive |
| 1 | 6 | 1.85 | 4 | 100 | 0 |
| 2 | 0 | 0.00 | 0 | 0 | 0 |
| 3 | 0 | 0.00 | 0 | 0 | 0 |
| 4 | 3 | 8.82 | 2 | 0 | 100 |
| 5 | 1 | 1.25 | 1 | 0 | 100 |
| 6 | 4 | 10.00 | 3 | 33 | 67 |
| 7 | 3 | 8.82 | 3 | 67 | 33 |
| 8 | 9 | 27.27 | 9 | 67 | 33 |
| 9 | 5 | 18.52 | 5 | 60 | 40 |
| 10 | 4 | 12.50 | 4 | 50 | 50 |
| 11 | 3 | 5.88 | 3 | 0 | 100 |
| 12 | 7 | 20.00 | 6 | 0 | 100 |
| 13 | 5 | 16.13 | 4 | 25 | 75 |
| 14 | 4 | 15.39 | 4 | 50 | 50 |

[a] Blocks are: 1) 17 May - 27 June, 2) 28 June - 4 July, 3) 5 - 11 July, 4) 12 - 18 July, 5) 19 - 25 July, 6) 26 July - 1 August, 7) 2 - 8 August, 8) 9 - 15 August, 9) 16 - 22 August, 10) 23 - 29 August, 11) 30 August - 5 September, 12) 6 - 12 September, 13) 13 - 19 September, 14) 20 - 26 September.

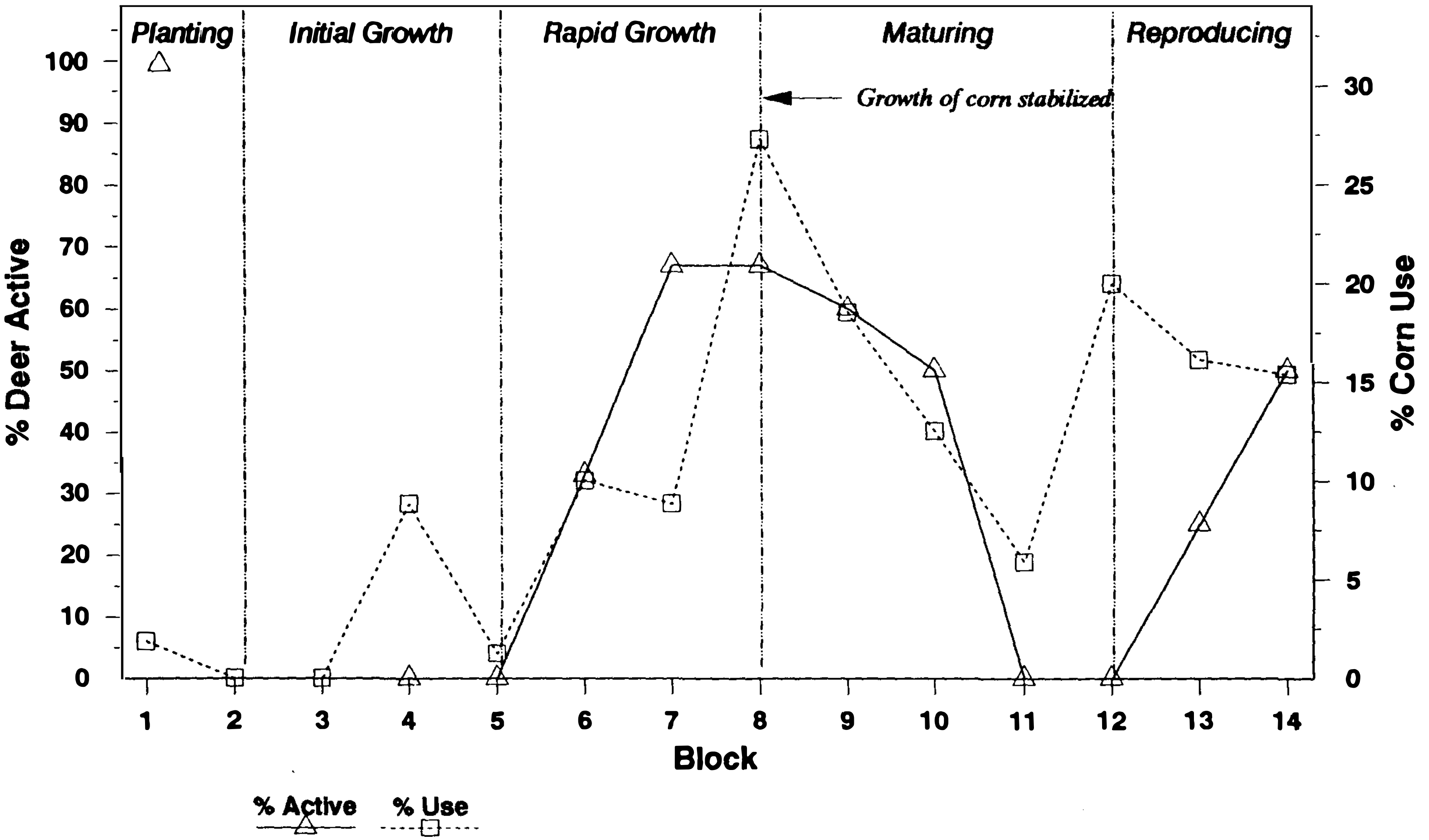

Figure 11. Percent use and percent activity of white-tailed deer in corn on Sand Lake National Wildlife Refuge, spring/ summer 1993. Blocks are: 1) 17 May - 27 June, 2) 28 June - 4 July, 3) 5 - 11 July, 4) 12 - 18 July, 5) 19 - 25 July, 6) 26 July - 1 August, 7) 2 - 8 August, 8) 9 - 15 August, 9) 16 - 22 August, 10) 23 - 29 August, 11) 30 August - 5 September, 12) 6 - 12 September, 13) 13 - 19 September, 14) 20 - 26 September.

growth" phase (28 June - 25 July), activity decreased to 0%. Both use and activity in corn increased in the "rapid growth" phase (19 July - 15 August). Percent activity peaked at 67% in the "rapid growth" phase as corn growth stabilized. Use of corn decreased and stabilized while activity in corn decreased (i.e., deer were inactive) in the "maturing" phase. The "reproducing" phase (20 - 26 September) resulted in increased activity to 50%.

## DISCUSSION

Modeling corn cover and forage characteristics in relationship to white-tailed deer use has received little attention considering the importance of corn in the Midwest region of the United States (Korschgen 1962, Mustard and Wright 1965, Watt et al. 1967, Pils et al. 1981, Kramlich 1985). Although variability existed between selected corn fields, cover characteristics of corn (i.e., height and density) increased quadratically for both measures of cover. Percent corn use by deer also increased quadratically, therefore, indicating that use of corn "tracks" corn growth. Comparisons between corn use and corn height indicated that percent corn use can best be predicted from corn height.

Use of a vegetation profile board (Nudds 1977) has not been previously used on agricultural vegetation. The profile board assessed the density of vegetation at different heights above the ground (Nudds 1977) which is important to quantifying cover for white-tailed deer. The physical structure of habitats has been recognized as important in determining bedding and feeding sites used by deer (Webb 1948). Use of a vegetation profile board was not a suitable compliment to height measurements for predicting deer use of corn. Because a vegetation profile board considers density within the vertical structure it may be useful in quantifying depredation in agricultural habitats.

Activity of deer in corn fields on SLNWR offers more compelling evidence of the importance of corn as an agricultural crop to white-tailed deer in the Midwest region of the United States. Use of corn began within 1 month of planting on SLNWR and continued throughout spring\summer 1993, except for the last week in June and the first week in July. As use began to increase in the "initial growth" phase, activity remained low. Corn height at this time was between 35 and 66 cm and capable of concealing a bedded deer (Bowyer 1986, Loft et al. 1987) or a deer that was laying down to take advantage of what cover was available while feeding on new green growth of corn. The "rapid growth" phase represented corn leaves that were rich in carbohydrates (Stoddart et al. 1975) and highly digestible (Burzlaff 1971) and corn plants dense enough to conceal an active deer (i.e., height = 88 to 149 cm; density = 41 to 60%) (Bowyer 1986, Loft et al. 1987); thus, deer were able to maximize use of cover and forage.

By the end of the "rapid growth" phase, corn plants had tasseled and height and density of corn had stabilized (Stoddart et al. 1975). Corn leaves in the "maturing" phase were lower in carbohydrates and less digestible than in the "rapid growth" phase and therefore offered less energy to deer (Stoddart et al. 1975). Consequently, use of corn and activity in corn decreased. Corn in the "maturing" phase was at maximum height (i.e., 149 cm) and density (i.e, 61 - 80%) and offered excellent cover characteristics (Bowyer 1986, Loft et al. 1987), yet forage characteristics (e.g., digestibility) would have declined. Activity increased in the "reproducing" phase, possibly due to increased forage quality of fruit.

## MANAGEMENT IMPLICATIONS

White-tailed deer use of corn on SLNWR was continuous from 11 July to 26 September 1993 and ranged from 1.25 - 27.27%. Without such a resource on SLNWR, deer would potentially disperse from SLNWR in periods of quality corn growth (i.e., the initial growth and rapid growth phases) and depredate corn fields on surrounding private lands. In winter months, standing corn on SLNWR has the potential to attract deer from surrounding lands and decrease landowner depredation complaints.

To alleviate depredation complaints on private lands, corn could be planted in a limited number of fields directly adjacent to SLNWR using strategic placement (e.g., if corn were absent from specific areas on SLNWR then private corn fields directly adjacent to SLNWR should be limited). Cooperation between landowners and SLNWR personnel would enhance corn field placement adjacent to SLNWR.

Not only do corn fields serve as a food base for deer but also as a source of cover. In years of increased water levels, corn also may serve in a capacity similar to emergent vegetation (i.e., a thick, tall stand of quality cover). Although the effectiveness of corn to white-tailed deer in the winter is unknown, it seems reasonable that greater quantities of standing corn and/or corn stubble would retain deer within Sand Lake's boundaries. Further research is warranted in the area of white-tailed deer/corn interactions in spring and winter including forage characteristics of corn throughout the growing season and effects of corn growth and availability on fawn reproduction and survival.

# Chapter 4: LOCALIZED MOVEMENTS AND SITE FIDELITY

Movement patterns of white-tailed deer have been documented in various regions and habitats (Schmautz 1949, Rongstad and Tester 1969, Nelson and Mech 1984, Nixon et al. 1991). Movement patterns are generally considered one of two types: short and long distance. Long distance movements are typical in northern latitudes where extreme weather is predictable (Hammerstrom and Blake 1939, Hunt and Mangus 1954, Carlsen and Farmes 1957, Hoskinson and Mech 1976, Nelson 1979, Nelson and Mech 1984). Hoskinson and Mech (1976) reported spring migration distances of 10.0 to 38.0 km to summer ranges in northern Michigan. Carlsen and Farmes (1957) reported Minnesota deer moving a maximum distance of 35.4 and 17.4 km for males and females, respectively, in winter in a coniferous forest.

Short distance movements have been documented where seasonal weather extremes are less pronounced (Hahn 1945, Hahn and Taylor 1950, Progulske and Baskett 1958, Thomas et al. 1964, Alexander 1968, Kammermeyer and Marchinton 1976). Kammermeyer and Marchinton (1976) reported an average dispersal movement of 4.4 km for 6 deer in Georgia. Hahn (1945) reported a maximum distance moved by white-tailed deer of 2.4 km in Texas. In Missouri, Progulske and Baskett

(1958) reported an average maximum distance moved by males of 3.1 km.

Deer present in agricultural areas of the Midwest generally exhibit seasonal movement patterns inconsistent with either type of traditional pattern. Sparrowe and Springer (1970) documented an average maximum distance between winter and summer ranges of 23.2 km for deer in South Dakota. In the prairie-deciduous forest of Minnesota, Carlsen and Farmes (1957) documented average movement of 15.6 km. Furthermore, Nixon et al. (1991) reported an average migration of yearling and adult does of 13 km in Illinois. These results indicate that prairie white-tailed deer do not exhibit traditionally long migratory patterns as found in some northern deer herds or short movements as found in southern herds. Sparrowe and Springer (1970) suggested that movement patterns were affected by seasonally changing habitat and hunting pressure.

One alternative to documenting traditional movement patterns (i.e., short or long distance) is to quantify localized movements as defined by home range size. Consequently, localized movement could be considered daily movement patterns of individual animals within home ranges. Home range size and location varies by season (Kammermeyer and Marchinton 1976), sex and age (Nixon et al. 1991), habitat quality and quantity (Dahlberg and Guttinger 1956), and density of deer (Nixon et al. 1991).

Another method for describing animal movements on a seasonal basis is site fidelity. Site fidelity has been documented extensively for mule deer (O. h. hemionus) (Gruell and Papez 1963, Garrott et al. 1987, Kufeld et al. 1989, Brown 1992) and black-tailed deer (O. h. sitkensis) (Schoen and Kirchhoff 1985). However, site fidelity analyses for white-tailed deer are limited (Tierson et al. 1985).

Site fidelity measures vary, as does interpretation of results. The distance between home range centroids in consecutive years has been used as a measure of fidelity (Schoen and Kirchhoff 1985, Garrott et al. 1987, Brown 1992). White and Garrott (1990) proposed a home range overlap technique as a means of measuring fidelity; however, their method was not quantitative.

More recently, Mielke and Berry (1982) proposed a nonparametric test based on multi-response permutation procedures (MRPP) to test for changes in an animal's area of utilization (also see Mielke et al. 1976, Zimmerman et al. 1985, Biondini et al. 1988). This method tests whether two or more sets of locations come from a common distribution and has power for detecting slight differences (B. S. Cade, pers. comm., U.S. Fish and Wildlife Service, National Ecology Research Center). The multi-response permutation procedure is a nonparametric test independent of assumptions regarding underlying distributions or homogeneity of variances. The MRPP statistic is based on the within-group average of pairwise distance measures between locations when groups are ignored (Biondini et al. 1988). Holzenbein and Marchinton (1992) used MRPP to assess fidelity of maturing-male white-tailed deer to natal range and common use of range between pairs of deer.

Considering the inconsistencies surrounding movement patterns of white-tailed deer, not only in measurements but techniques as well, the purpose of this research was to evaluate winter/spring movements of white-tailed deer on SLNWR and nearby private lands using quantitative methods. Specific objectives were: 1) to calculate seasonal home range size and relate size to localized movements, 2) to evaluate intraseasonal site fidelity, and 3) to evaluate interseasonal site fidelity.

## METHODS

Radio-collared deer were monitored from 6 January to 28 June 1993 and 13 January to 27 June 1994, as described in Chapter 1. Individual deer were monitored every 20 hours; therefore, serial locations were assumed to be independent (Swihart and Slade 1985). Individual deer were monitored throughout both years unless unforseen circumstances (e.g., mortality, malfunctioned transmitter) terminated monitoring early.

## Localized Movement

Ninety-five and 50% home range contours were calculated for each deer per season using the adaptive kernel method (Worton 1989) described in Chapter 1. Home range contours were imported into PC ARC/INFO (ESRI, Inc., Redlands, California), a GIS, and generated into home range coverages that included 95 and 50% (i.e., core) home range contours (ESRI 1991a). Size of each 95% home range and core area was calculated using a GIS (ESRI 1991a). Analysis of variance applied to ranked home range size (Friedman 1937, Conover and Iman 1981, Sokal and Rohlf 1981) was used to assess variation between sex, age, season, and year for both 95% and core area home ranges. Analysis of variance tests were considered significant at $P \leq 0.05$.

## Intraseasonal Site Fidelity

Intraseasonal site fidelity was defined as the tendency of an individual animal to return to a seasonal home range. For example, if a deer wintered within the same home range each year then the individual would be exhibiting intraseasonal site fidelity. Intraseasonal site fidelity was evaluated with 2 comparisons: 1, winter 1993/winter 1994 locations and 2, spring 1993/spring 1994 locations, for all radio-collared deer that were monitored both years. Multi-response permutation procedures (Mielke and Berry 1982) were used to evaluate fidelity by measuring central tendency and dispersion of the cumulative distribution of locations (i.e., X and Y coordinates) in each comparison (Slauson et al. 1991). Intraseasonal site fidelity also was evaluated by measuring 95% home range overlap, expressed as percentage of overlap of 1993 home range with the corresponding home range in 1994 using a GIS (ESRI 1991a).

**Interseasonal Site Fidelity**

Interseasonal site fidelity was defined as the tendency of an individual animal to remain within home ranges following seasonal changes in the environment. For example, if a deer remained in a specific home range in winter and spring, then the individual would be exhibiting interseasonal site fidelity. Interseasonal site fidelity was evaluated using MRPP (Slauson et al. 1991) and range-overlap techniques, similar to intraseasonal site fidelity.

Interseasonal site fidelity was evaluated with 4 comparisons: 1, winter 1993/spring 1993 locations; 2, winter 1994/spring 1994 locations; 3, spring 1993/winter 1994 locations; and 4, winter 1993/spring 1994 locations. Range-overlap was expressed as percentage of overlap of the initial home range with the latter home range in the comparison using a GIS (ESRI 1991a). For example, range-overlap in comparison 1 would be calculated as the percentage of the winter 1993 home range overlapped by the spring 1993 home range.

Multi-response permutation procedures were considered significant at $P \leq 0.05$. Extent of range-overlap was defined as: 0 - 33% overlap, low fidelity; 34 - 66% overlap, moderate fidelity; and 67 - 100% overlap, high fidelity.

## RESULTS

### Localized Movement

Ninety-five percent home range size did not differ by sex, age, season, or year ($\underline{P} > 0.05$) (Table 8). Mean 95% home range size was 437 ha (SE = 38.4, Range = 11-1624, $\underline{n}$ = 81).

A 2-factor interaction occurred ($\underline{F}$ = 3.97, df = 1, $\underline{P}$ = 0.050) between sex and age for core area size (Table 8). Mean core area size for yearling (i.e., 1.5-year-old) males (Mean = 59 ha, SE = 7.9, Range = 34-77, $\underline{n}$ = 6) was larger ($\underline{F}$ = 8.50, df = 1, $\underline{P}$ = 0.005, and $\underline{F}$ = 3.86, df = 1, $\underline{P}$ = 0.053) than mean core area size for yearling females (Mean = 22 ha, SE = 5.5, Range = 4-44, $\underline{n}$ = 7) and adult (i.e., $\geq$ 2.5-year-old) females (Mean = 39 ha, SE = 3.2, Range = 2-79, $\underline{n}$ = 6) (Fig. 12). Mean core area size for adult males (Mean = 48 ha, SE = 6.1, Range = 1-81, $\underline{n}$ = 16) was larger ($\underline{F}$ = 6.44, df = 1, $\underline{P}$ = 0.013) than mean core area size for yearling females (Mean = 22 ha, SE = 5.5, Range = 4-44, $\underline{n}$ = 7) (Fig. 12). Mean core area size for adult females (Mean = 39 ha, SE = 3.2, Range = 2-79, $\underline{n}$ = 6) was larger ($\underline{F}$ = 3.70, df = 1, $\underline{P}$ = 0.058) than mean core area size for yearling females (Mean = 22 ha, SE = 5.5, Range = 4-44, $\underline{n}$ = 7) (Fig. 12).

Table 8. Seasonal 95% and 50% home range size (ha) of white-tailed deer on Sand Lake National Wildlife Refuge, South Dakota, 1993-1994.

| | Winter 1993 | | | Spring 1993 | | | Winter 1994 | | | Spring 1994 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deer[a] | n | 95% (SE) | 50% (SE) | n | 95% (SE) | 50% (SE) | n | 95% (SE) | 50% (SE) | n | 95% (SE) | 50% (SE) |
| All | 24 | 373 ( 54) | 64 (11) | 24 | 457 ( 83) | 68 (14) | 15 | 406 ( 69) | 67 (13) | 18 | 524 ( 97) | 94 (27) |
| F | 17 | 341 ( 69) | 58 (13) | 17 | 396 ( 85) | 48 ( 8) | 11 | 368 ( 63) | 59 (12) | 14 | 512 (107) | 74 (16) |
| M | 7 | 449 ( 80) | 76 (18) | 7 | 604 (197) | 115 (40) | 4 | 512 (204) | 90 (37) | 4 | 567 (250) | 164(112) |
| F/1.5 | 6 | 245 ( 25) | 31 ( 7) | 6 | 298 ( 98) | 48 (17) | 1 | 559 ( - ) | 33 ( -) | 1 | 404 ( - ) | 39 ( -) |
| F/2.5+ | 11 | 394 (104) | 73 (19) | 11 | 450 (121) | 49 ( 9) | 10 | 349 ( 67) | 62 (13) | 13 | 528 (115) | 77 (17) |
| M/1.5 | 5 | 482 (109) | 89 (23) | 5 | 768 (233) | 148 (47) | 1 | 1008 ( - ) | 175 ( -) | 1 | 429 ( - ) | 56 ( -) |
| M/2.5+ | 2 | 366 ( 78) | 44 ( 9) | 2 | 194 (183) | 33 (32) | 3 | 346 (169) | 61 (33) | 3 | 613 (348) | 199(150) |

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[a] Deer categories are: All) all deer combined, F) female, M) male, F/1.5) female/1.5 year old, F/2.5+) female/2.5+ years old, M/1.5) male/1.5 years old, M/2.5+) male/2.5+ years old.

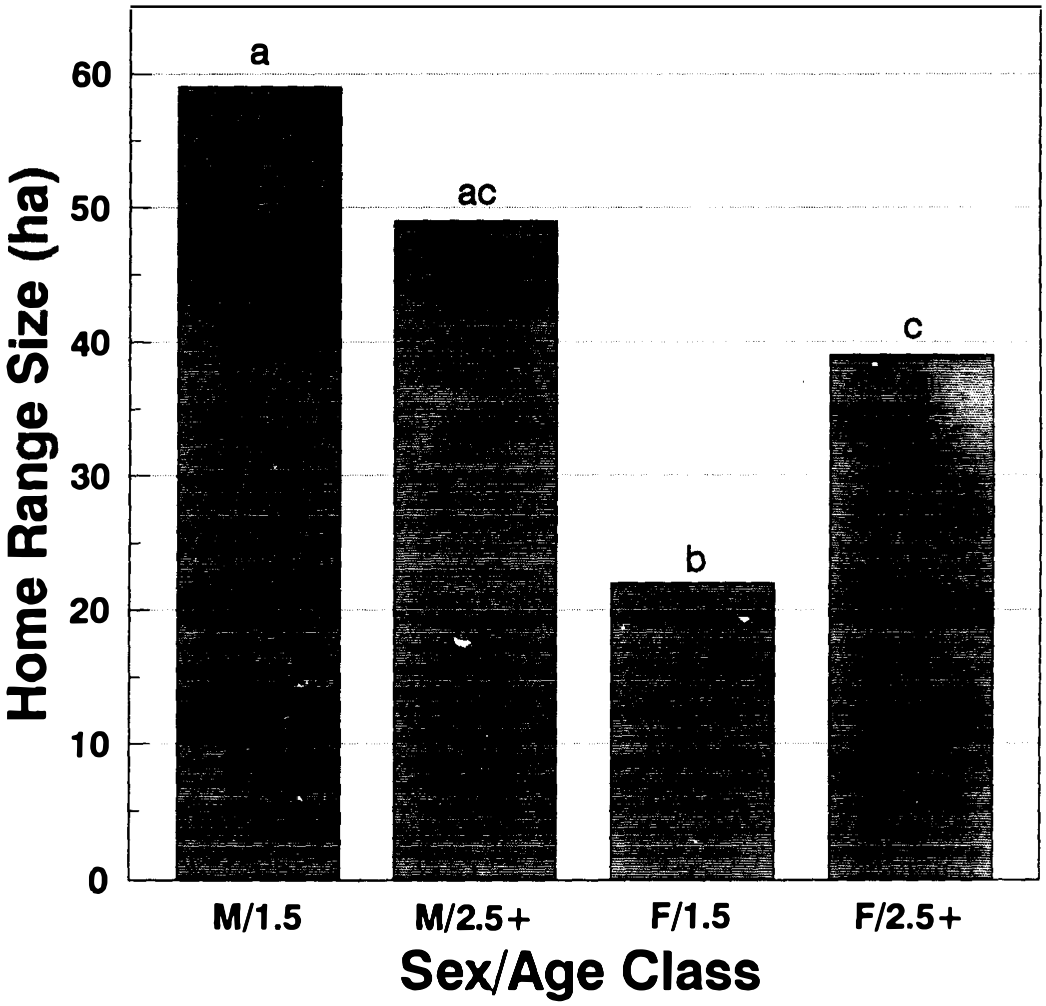

Figure 12. Mean white-tailed deer core area size by sex and age on Sand Lake National Wildlife Refuge, South Dakota, 1993-1994. Sex/Age classes are: M/1.5) 1.5 years old male, M/2.5+) 2.5+ year old male, F/1.5) 1.5 year old female, F/2.5+) 2.5+ year old female. Sex/Age classes with the same letter represent no difference in mean core area size ($P > 0.05$).

### Site Fidelity

Multi-response permutation procedures resulted in 1 incident (i.e., 14%, $n$ = 7) of high intraseasonal site fidelity ($\delta$ = -1.7, $P$ = 0.067) in comparison 1 (i.e., winter 1993/winter 1994) and 0% ($n$ = 7) high intraseasonal site fidelity ($P < 0.001$) in comparison 2 (i.e., spring 1993/spring 1994) (Table 9). However, mean intraseasonal range-overlap was 49% (SE = 13.8, Range = 0-100, $n$ = 7) in comparison 1 and 65% (SE = 14.5, Range = 0-100, $n$ = 7) in comparison 2 (Table 9), indicating moderate site fidelity in both comparisons.

Multi-response permutation procedures resulted in 8% ($n$ = 53) high interseasonal site fidelity ($P > 0.05$) over all comparisons (Table 9). However, mean interseasonal range-overlap was 53% (SE = 5.0, Range = 0-100, $n$ = 53) (Table 9), indicating moderate site fidelity.

## DISCUSSION

Localized movements encompassing 437 ha by white-tailed deer in this agricultural/wetland complex throughout winter and spring were relatively concentrated considering the dynamic nature of such landscapes (i.e., changing crop types and growth patterns). In comparison, reports of home range size include estimates of 161-480 ha (Rongstad and Tester 1969), 26.4 ha (Hoskinson and Mech 1976), 700 ha (Sparrowe and Springer 1970), and 135 ha (Tierson et al. 1985) in

Table 9. Site fidelity based on multi-response permutation procedures (MRPP) and percent range-overlap of white-tailed deer at Sand Lake National Wildlife Refuge, South Dakota, 1993-1994.

| | | | MRPP > 0.05 (%) | Overlap (%)[b] | |
|---|---|---|---|---|---|
| Type | Comparison[a] | n | $\bar{x}$ | $\bar{x}$ | SE |
| Intraseasonal | 1 | 7 | 14 | 49 | 13.8 |
| | 2 | 7 | 0 | 65 | 14.5 |
| Interseasonal | . | 53 | 8 | 53 | 5.0 |

[a] Comparisons are: 1) winter/winter locations, 2) spring/spring locations, .) winter/spring locations.

[b] Percent of first seasons 95% home range overlapped by the second seasons 95% home range.

winter and 61-247 ha (Michael 1965), 250 ha (Sparrowe and Springer 1970), and 45-142 ha (Beier and McCullough 1990) yearlong. In Georgia, Kammermeyer and Marchinton (1976) found male home ranges in autumn, prior to dispersal, to average much larger than in summer (207 versus 71 ha). Similarly, Nixon et al. (1991) found female ranges generally to be larger in winter than in summer where deer were not restricted by deep snow. In contrast, Hoskinson and Mech (1976) and Nelson and Mech (1981) found deer withdrawing to a small part of their summer range in winter. Home ranges are typically larger for males than females (Michael 1965, Gavin et al. 1984, Nixon et al. 1991). However, 95% home ranges did not differ by sex, age, season, or year on SLNWR.

Often, all requirements of a species can be provided in a small area. Thus, home range size of species need not be large (Sanderson 1966, Sparrowe and Springer 1970). Dahlberg and Guettinger (1956) found that Wisconsin deer remained in a small area until habitat conditions deteriorated or they were forced to move because of disturbances. Results of core area size calculations on SLNWR indicated that individual deer were capable of obtaining all life requisites within one confined area throughout winter and spring. Such restricted movement was possibly due to the interspersion of habitats within the landscape, which allowed for close proximity of food and cover. Because neither 95% nor core area size differed by season, traditional home range restriction in winter was not evident at SLNWR. In winter 1994, when snowfall was above normal, 95% home range size (i.e., 406 ha) did not indicate restricted localized movement.

Multi-response permutation procedures indicated low intra- and interseasonal site fidelity of white-tailed deer on SLNWR. Multi-response permutation procedures evaluated dispersion and central tendency of the cumulative distribution of locations, thus MRPP is sensitive to slight changes in distribution (B. S. Cade, pers. comm., U.S. Fish and Wildlife Service, National Ecology Research Center). By interpreting site fidelity using MRPP and range-overlap estimates, biological significance of site fidelity is not lost. Although locational distributions between years (i.e., intraseasonal site fidelity) and seasons (i.e., interseasonal site fidelity) were not similar, range-overlap indicated some degree of fidelity to previous ranges. Therefore, site fidelity, both intra- and interseasonal, of white-tailed deer on SLNWR may be considered moderate.

Moderate site fidelity may be another effect of the dynamic nature of SLNWR's agricultural/wetland landscape. Although an individual's tendency is to remain in (i.e., intraseasonal), or return to (i.e., interseasonal), a specific range, changing agricultural practices may preclude exact stability of a range location within the landscape. Thirty-two percent of SLNWR and adjacent private land use changed between 1993 and 1994. Of the 32% that changed, 85% was classified as agricultural in 1993. Site fidelity may therefore be related to changes in gross habitat characteristics.

## MANAGEMENT IMPLICATIONS

Limited localized movements indicated that white-tailed deer do not traverse long distances throughout a day and thus management practices (e.g., winter supplemental feeding, late season reduction hunts) can be restricted to specific problem areas. Depredation complaints on surrounding private lands regarding SLNWR resident deer must be considered carefully. Considering the limited movements of radio-collared deer, such complaints may not necessarily be stimulated by resident deer on SLNWR.

Moderate intraseasonal site fidelity indicated that at least some of the same deer return to SLNWR year after year, or never left SLNWR as supported by findings of moderate interseasonal site fidelity. Unknown are the consequences of severely diminishing a population through intensive hunting and how vacant ranges are exploited by other individuals.

# Chapter 5: SEXUAL SEGREGATION

Sexual segregation has been reported for many ungulates including elk (Peek and Lovaas 1968), moose (Miquelle et al. 1992), mule deer (Bowyer 1984, Ordway and Krausman 1986), bighorn sheep (Geist and Petocz 1977, Shank 1982), caribou (Rangifer tarandus) (Cameron and Whitten 1979), red deer (Cervus elaphus) (Watson and Staines 1978, Clutton-Brock et al. 1982), African buffalo (Syncerus caffer) (Prins 1989), and white-tailed deer (McCullough 1979, Beier 1987, McCullough et al. 1989, Beier and McCullough 1990, Weckerly and Nelson 1990, Lagory et al. 1991). Sexual segregation generally results in resource partitioning of habitat (Bowyer 1984, Ordway and Krausman 1986, McCullough et al. 1989, LaGory et al. 1991, Miquelle 1992) or forage (Staines and Crisp 1978, Shank 1982, Staines et al. 1982, McCullough 1985, Beier 1987, Weckerly and Nelson 1990). Although sexual segregation has been reported for a variety of species, there is no agreement as to causation. Several hypotheses have been proposed to explain segregation including responses to predation, decline in body condition during rut, sociality, and size dimorphism.

Predator avoidance can segregate males from females as a result of exhaustion from reproduction (Geist and Bromley 1978). However, females segregate from males because of selection of habitats that provide cover for neonates, regardless of habitat condition (McCullough 1979, Geist 1982, Edwards 1983, Miquelle et al. 1992). While females select habitats that provide superior security cover, males select areas that provide a high forage base (Geist 1982, Bowyer 1984, Clutton-Brock et al. 1987, McCullough et al. 1989, Main and Coblentz 1990).

Staines (1976) and Watson and Staines (1978) have proposed that red deer are forced to select winter habitats that minimize energy losses, because of a decline in body condition during rut. However, Clutton-Brock et al. (1987) disagree with this hypothesis based on observations of red deer on the island of Rhum: red deer increased use of unprotected areas on windy days. Morgantini and Hudson (1981) suggested that winter segregation of bighorn sheep decreased energy expenditure due to intersexual competition of rams even when females were no longer receptive.

Verme (1988) and McCullough (1979) have proposed that male white-tailed deer segregate from females in summer to establish dominance hierarchies. Verme (1988) further hypothesized that male white-tailed deer aggregated in open habitats to reduce damage to developing antlers and provide protection from predators.

It has been reported for several species (i.e., white-tailed deer, mule deer, and red deer) that males consume an inferior diet when compared to females. Beier (1987) reported adult female deer on the George Reserve in Michigan consistently selected higher quality diets than did adult males. Bowyer (1984) reported that male southern mule deer seemed to inhabit inferior ranges in periods of sexual segregation as did Ordway and Krausman (1986) for desert mule deer. Similarly, Clutton-Brock et al. (1987) reported larger male red deer subsisting on diets that were lower in available protein than smaller female red deer. Because of Kleiber's (1961) law that basal metabolic rate is related to body weight by the equation:

$$BMR = 70\ W^{0.75}$$

where: BMR = basal metabolic rate
W = body weight

larger males should have lower nutritional requirements per unit body weight than females, which would allow males to subsist on lower quality food than females. Males also would select different habitats, have different activity patterns, and forage differently to reduce energy expenditure (Miquelle et al. 1992). However, this hypothesis has been refuted by several authors (Shank 1982, Weckerly et al. 1987, Lagory et al 1991). LaGory et al. (1991) reported that male white-tailed deer on Ossabaw Island, Georgia, used higher quality habitat than females. Similarly, Shank (1982) found that male bighorn sheep used habitat that was superior to those used by females.

Weckerly and Nelson (1990) also rejected the hypothesis that females consume a higher quality diet than males. Despite the general acceptance of sexual segregation among ungulates, there are still reports to the contrary. For example, Tierson et al. (1985) found no evidence of niche separation between sexes for white-tailed deer in the Adirondack Mountains of New York.

The purpose of this research was to evaluate sexual segregation patterns as related to spatial and temporal habitat use on SLNWR. Specific objectives were: 1) to assess central tendency shifts and dispersion effects within cumulative distributions between males and females, 2) to calculate range-overlap between males and females, and 3) to compare habitats within overlapping male and female ranges.

## METHODS

Radio-collared deer were monitored from 6 January to 28 June 1993 and 13 January to 27 June 1994, as described in Chapter 1. Multi-response permutation procedures were used to assess central tendency shifts and dispersion affects of cumulative distribution of seasonal locations (i.e., X and Y coordinates), as described in Chapter 3, between groups of deer (Mielke and Berry 1982, Slauson et al. 1991). Male and female white-tailed deer were grouped according to home range juxtaposition based on mean seasonal home range radius. For example, if 2 home ranges from deer of the opposite sex were within a distance equal to the mean radius of all home ranges (i.e., based on a circular home range) for that season, then MRPP analyses were conducted. Home range size was calculated according to methods described in Chapter 1. Multi-response permutation procedures were considered significant at $P \leq 0.05$.

Sexual segregation also was evaluated by measuring seasonal 95% home range overlap, expressed as percentage of overlap of individual deer home ranges by a composite of all seasonal home ranges of the opposite sex using PC ARC/INFO (ESRI Inc., Redlands, California), a GIS (ESRI 1991a). Similar to MRPP analyses, individual deer within a distance equal to the mean radius of seasonal home ranges were included in range-overlap analyses. Range-overlap identified sexual segregation in the following manner: 0 - 33% overlap, high segregation; 34 - 66% overlap, moderate segregation; and 67 - 100% overlap, low segregation.

Wilcoxon matched-pairs signed-ranks tests were used to compare seasonal habitat use within overlapping space to seasonal habitat use within individual 95% home ranges (Daniel 1990). Proportional area by habitat within overlapping space and individual 95% home ranges was calculated using a GIS (ESRI 1991a). Mann-Whitney U tests were used to evaluate differences in habitat use within individual 95% home ranges between the sexes by season (Daniel 1990). Wilcoxon matched-pairs signed-ranks tests and Mann-Whitney U tests were considered significant at $P \leq 0.05$.

## RESULTS

Mean radius of seasonal home ranges were: winter 1993, 1,035.2 m (SE = 69.08, Range = 589.0-1,965.0, n = 24); spring 1993, 1,102.4 m (SE = 99.72, Range = 187.1-2,202.5, n = 24); winter 1994, 1,080.9 m (SE = 91.44, Range = 605.0-1,791.2, n = 15); and spring 1994, 1,207.8 m (SE = 107.71, Range = 447.8-2,273.6, n = 18). Group size varied between 2 and 3 home ranges.

### Winter

Multi-response permutation procedures were highly significant ($P < 0.001$) (i.e., sexual segregation occurred) within 81% (n = 27) of the groups in winter 1993 and 100% (n = 6) of the groups in winter 1994. Similarly, 4 groups (i.e., 15%, n = 27) in winter 1993 were significantly different ($P < 0.05$).

Mean range-overlap for males and females in winter 1993 was 66% (SE = 4.9, Range = 24-100, n = 7) and 56% (SE = 2.3, Range = 0-100, n = 15), respectively. Similarly, range-overlap for males and females in winter 1994 was 68% (SE = 9.2, Range = 0-100, n = 4) and 35% (SE = 6.2, Range = 0-100, n = 6), respectively. Mean range-overlap for males and females, years combined, was 67% (SE = 10.1, Range = 24-100, n = 11) and 50% (SE = 7.8, Range = 0-100, n = 21), respectively (Fig. 13). Overall mean range-overlap in winter was 56% (SE = 6.3, Range = 0-100, $n = 32$) (Fig. 13). Therefore, sexual segregation was considered moderate in winter.

Wilcoxon matched-pairs signed ranks tests indicated that use of row crops other than corn, dense-cover grasslands, and water were lower ($P < 0.05$) in overlapping space than in individual 95% home ranges in winter 1993 (Table 10). In contrast, use of alfalfa in winter 1993 was lower ($P < 0.05$) in individual 95% home ranges than in overlapping space (Table 10). In winter 1994 use of corn and treebelts were lower ($P < 0.05$) in overlapping space than in individual 95% home ranges (Table 10).

Although habitats differed between overlapping space and individual home ranges (Table 10), proportional use within individual 95% home ranges did not differ between males and females ($P > 0.05$), except for treebelts in winter 1994 (Table 11). Use of treebelts by females (Mean = 3.05%, SE = 0.512, Range = 1.60-5.15, $n = 6$) was higher ($U = 2.0$, df = 1, $P = 0.033$) than use of treebelts by males (Mean = 1.45%, SE = 0.242, Range = 0.88-2.06, $n = 4$) (Table 11).

### Spring

Multi-response permutation procedures were highly significant ($P < 0.001$) within 100% ($n = 19$) of groups in spring 1993 and 92% ($n = 13$) of groups in spring 1994.

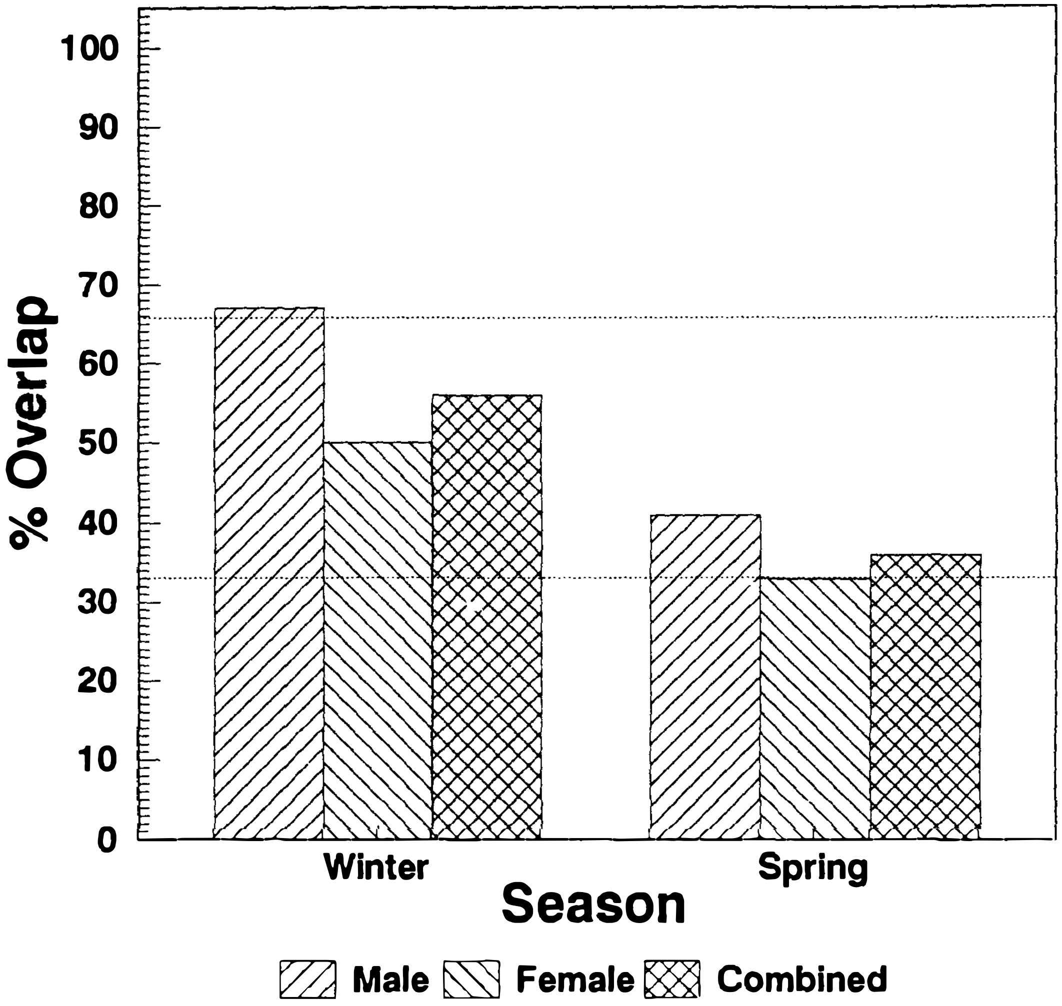

Figure 13. Percent range-overlap for males, females, and sexes combined for white-tailed deer by season on Sand Lake National Wildlife Refuge, South Dakota, 1993-1994. Dashed lines represent segregation break points: 0-33% overlap) high segregation, 34-66% overlap) moderate segregation, and 67-100% overlap) low segregation.

Table 10. Comparison of habitat use between overlapping space and individual 95% home ranges by sex of white-tailed deer for winter and spring 1993-1994 at Sand Lake National Wildlife Refuge, South Dakota.

| | Winter 1993 | | Spring 1993 | | Winter 1994 | | Spring 1994 | |
|---|---|---|---|---|---|---|---|---|
| Type[a] | Z[b] | P[c] | Z | P | Z | P | Z | P |
| CR | 0.07 | 0.95 | 2.17 | 0.03*[d] | 1.96 | 0.05* | 1.02 | 0.31 |
| SG | -0.45 | 0.65 | 2.98 | 0.00* | 1.35 | 0.18 | -0.47 | 0.64 |
| RC | 2.90 | 0.00* | -0.28 | 0.78 | 1.10 | 0.27 | 1.17 | 0.24 |
| AF | -2.14 | 0.03**[e] | 2.13 | 0.03* | 0.28 | 0.78 | 2.43 | 0.02* |
| DC | 2.50 | 0.01* | 1.64 | 0.10 | 1.52 | 0.13 | 1.07 | 0.29 |
| BR | -1.48 | 0.14 | -0.37 | 0.71 | 0.56 | 0.58 | 0.39 | 0.70 |
| TR | 1.11 | 0.27 | 1.30 | 0.19 | 2.10 | 0.04* | -0.47 | 0.64 |
| WT | 3.58 | 0.00* | -0.47 | 0.64 | 0.68 | 0.50 | 1.18 | 0.24 |
| EM | -0.72 | 0.47 | 0.36 | 0.72 | 0.51 | 0.61 | 2.35 | 0.02* |
| OT | 1.25 | 0.21 | 0.32 | 0.75 | 0.00 | 1.00 | 2.76 | 0.01* |

[a] Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelts, WT) water, EM) emergent vegetation, OT) other habitats.

[b] Z: Wilcoxon matched-pairs signed ranks Z statistic.

[c] P: P-value for Wilcoxon matched-pairs signed ranks tests.

[d] *: Habitat use of overlapping space is significantly less than habitat use of 95% home range ($P < 0.05$).

[e] **: Habitat use of 95% home range is significantly less than habitat use of overlapping space ($P < 0.05$).

Table 11. Differences between percent habitat use within 95% home ranges by male and female white-tailed deer in winter and spring on Sand Lake National Wildlife Refuge, South Dakota, 1993-1994.

| | Winter 1993 | | Spring 1993 | | Winter 1994 | | Spring 1994 | |
|---|---|---|---|---|---|---|---|---|
| Type[a] | M.[b] | F.[c] | M. | F. | M. | F. | M. | F. |
| CR | 7.4 | 5.2 | 11.3 | 9.7 | 9.3 | 10.5 | 21.4 | 18.3 |
| SG | 7.5 | 6.0 | 8.3 | 13.1 | 5.5 | 11.7 | 11.4 | 13.9 |
| RC | 1.2 | 3.5 | 0.5 | 1.0 | 0.3 | 1.0 | 5.4 | 4.9 |
| AF | 7.3 | 6.0 | 9.0 | 7.3 | 6.2 | 6.0 | 3.3 | 5.1 |
| DC | 1.7 | 1.4 | 5.7 | 6.5 | 3.4 | 7.3 | 3.5 | 7.0 |
| BR | 23.4 | 22.4 | 27.1 | 22.9 | 32.9 | 23.1 | 29.1 | 24.6 |
| TR | 1.9 | 1.3 | 4.8 | 3.7 | 1.5 | 3.1*[d] | 5.5 | 5.5 |
| WT | 19.1 | 14.9 | 15.3 | 7.8 | 10.8 | 6.4 | 6.8 | 4.8 |
| EM | 28.8 | 38.2 | 15.7 | 23.8 | 28.1 | 26.3 | 11.3 | 14.2 |
| OT | 1.7 | 1.0 | 2.5 | 4.3 | 2.3 | 4.6 | 2.4 | 1.8 |
| Total | 100.0 | 99.9 | 100.2 | 100.1 | 100.3 | 100.0 | 100.1 | 100.1 |

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[a] Habitats are: CR) corn, SG) small grain, RC) row crops other than corn, AF) alfalfa, DC) dense-cover grassland, BR) brome-dominated grassland, TR) treebelts, WT) water, EM) emergent vegetation, OT) other habitats.

[b] M.: Male

[c] F.: Female

[d] * represents significant difference between males and females (Mann-Whitney U test, $P \leq 0.05$).

Additionally, 8% of groups in spring 1994 were different ($P < 0.05$).

Mean range-overlap for males and females in spring 1993 was 39% (SE = 4.0, Range = 0-79, $n$ = 7) and 29% (SE = 2.4, Range = 0-100, $n$ = 14), respectively. Mean range-overlap for males and females in spring 1994 was 45% (SE = 6.5, Range = 15-72, $n$ = 4) and 41% (SE = 5.0, Range = 0-100, $n$ = 8), respectively. Mean range-overlap for males and females, years combined, was 41% (SE = 7.9, Range = 0-79, $n$ = 11) and 33% (SE = 7.6, Range = 0-100, $n$ = 22), respectively (Fig. 13). Overall mean range-overlap in spring was 36% (SE = 5.7, Range = 0-100, $n$ = 33) (Fig. 13). Therefore, sexual segregation, according to range-overlap techniques, was considered moderate-high in spring.

Wilcoxon matched-pairs signed-ranks tests indicated that use of corn, small grain, and alfalfa was lower ($P < 0.05$) in overlapping space than in individual 95% home ranges in spring 1993 (Table 10). Use of alfalfa, emergent vegetation, and other habitats was lower ($P < 0.05$) in overlapping space than in individual 95% home ranges in spring 1994 (Table 10). Similar to winter, proportional use within 95% home ranges did not differ ($P > 0.05$) between males and females in spring (Table 11).

## DISCUSSION

Sexual segregation, inferred by differential use of space and habitats, must be quantified with respect to both temporal and spatial variation, especially when habitat preference patterns do not differ between sexes. McCullough et al. (1989) reported resource partitioning between the sexes of white-tailed deer based on mean overlap of home ranges by season of approximately 56% (calculated from Schoener's [1970] index of spatial overlap).

Based on MRPP results coupled with range-overlap estimates, sexual segregation existed on SLNWR with respect to differences in use of space. Multi-response permutation procedures have power to detect slight differences between cumulative distributions (B. S. Cade. pers. comm., U.S. Fish and Wildlife Service, National Ecology Research Center). Although MRPP results indicated high sexual segregation, range-overlap was moderate (i.e., 56%) in winter and moderate-high (i.e., 36%) in spring. Therefore, sexual segregation on SLNWR may be classified as moderate in winter and high in spring; therefore, these results support conclusions of McCullough et al. (1989) relative to describing sexual segregation with respect to differential use of space by white-tailed deer.

Results also support conclusions of McCullough et al. (1989) regarding differential habitat use by sexes. Although deer were separated in space, habitats were used similarly by sex within individual 95% home ranges in both seasons. Despite similar use by sexes, differences in proportional habitats did occur between overlapping space and individual 95% home ranges indicating sexual segregation within some habitats. Row crops other than corn, dense-cover grasslands, corn, and treebelts were used less in overlapping space in winter, while corn, alfalfa, and emergent vegetation were used less in overlapping space in spring. Thus, sexes segregated on habitats used for forage and cover characteristics in both seasons.

Results from this study do not, however, support the theories regarding sexual segregation of white-tailed deer based on differences in use of foods (McCullough 1985, Beier 1987) or differences in nutritional quality of foods (Beier 1987). Even though segregation was occurring in space, habitats were used equally by males and females. Segregation in space within specific habitat patches may be related to density of deer, size of patches, and interspersion of patches.

Reasons for sexual segregation by white-tailed deer on SLNWR are difficult to address without further studies designed to evaluate differences in use of food and quality of forage between the sexes (McCullough et al. 1989). Differential use of space and habitats alone will not explain sexual segregation by white-tailed deer. Differences in rumen size, intestinal lengths, and presence of ubiquitous, high quality forage may result in sexual segregation (McCullough 1979, Weckerly 1989, Jenks et al. 1994). Evaluation of density effects on sexual segregation may be a necessary in landscapes such as SLNWR where deer densities are high (i.e., 16.5 deer/km$^2$ post hunt [D. E. Naugle, unpubl. data]).

## MANAGEMENT IMPLICATIONS

In regions where hunting is the primary method of white-tailed deer management (e.g., Midwest region, United States), sexual segregation may inhibit goals to limit population density. Population sex ratios may be altered by hunting due to spatial segregation by the sexes. In high density populations, unbalanced populations skewed toward females will seldom increase productivity because of increased female-female competition (McCullough et al. 1989).

Although habitat use was similar for sexes, habitat manipulations that consider spatial differences between the sexes could help refine objectives related to population control. Adequate interspersion tends to facilitate spatial separation while allowing both sexes to utilize preferred habitats.

# Chapter 6: SUMMARY OF MANAGEMENT IMPLICATIONS

Due to low availability of agricultural crops, especially row crops other than corn (e.g., soybeans) and treebelts on SLNWR, these habitats were frequently identified as preferred habitats for white-tailed deer considering that preference analyses are dictated by availability of habitat. Increased conservation of standing winter crops would undoubtedly restrict deer movement off SLNWR and decrease depredation complaints. In severe winters, such as winter 1994, treebelts served as a supplemental source of cover to resident animals when emergent vegetation was inaccessible.

Observed patterns of habitat use (i.e., importance) indicated that emergent vegetation and brome-dominated grasslands were crucial habitats to white-tailed deer on SLNWR. Large expanses of emergent vegetation on SLNWR serve as dominant wintering areas for resident (i.e., refuge) deer and deer that migrate to SLNWR (B. J. Kernohan, unpubl. data). Brome-dominated grasslands interspersed with dense-cover grasslands may provide suitable fawning habitat as well as high quality forage. Management strategies relating to preferred habitats alone neglect the importance of habitats such as emergent vegetation and brome-dominated grasslands in white-tailed deer management.

White-tailed deer use of corn on SLNWR was continuous from 11 July to 26 September 1993 and ranged from 1.25 - 27.27%. Without such a resource on SLNWR, deer would potentially disperse from SLNWR in periods of quality corn growth (i.e., the initial growth and rapid growth phases) and depredate corn fields on surrounding private lands. In winter months, standing corn on SLNWR has the potential to attract deer from surrounding lands and decrease landowner depredation complaints.

To alleviate depredation complaints on private lands, corn could be planted in a limited number of fields directly adjacent to SLNWR using strategic placement (e.g., if corn were absent from specific areas on SLNWR then private corn fields directly adjacent to SLNWR should be limited). Cooperation between landowners and SLNWR personnel would enhance corn field placement adjacent to SLNWR.

Not only do corn fields serve as a food base for deer but also as a source of cover. In years of increased water levels, corn also may serve in a capacity similar to emergent vegetation (i.e., a thick, tall stand of quality cover). Although the effectiveness of corn to white-tailed deer in the winter is unknown, it seems reasonable that greater quantities of standing corn and/or corn stubble would retain deer within Sand Lake's boundaries. Further research is warranted in the area of white-tailed deer/corn interactions in spring and winter including forage characteristics of corn throughout the growing season and effects of corn growth and availability on fawn reproduction and survival.

Limited localized movements indicated that white-tailed deer do not traverse long distances throughout a day and thus management practices (e.g., winter supplemental feeding, late season reduction hunts) can be restricted to specific problem areas. Depredation complaints on surrounding private lands regarding SLNWR resident deer must be considered carefully. Considering the limited movements of radio-collared deer, such complaints may not necessarily be stimulated by resident deer on SLNWR.

Moderate intraseasonal site fidelity indicated that at least some of the same deer return to SLNWR year after year, or never left SLNWR as supported by findings of moderate interseasonal site fidelity. Unknown are the consequences of severely diminishing a population through intensive hunting and how vacant ranges are exploited by other individuals.

In regions where hunting is the primary method of white-tailed deer management (e.g., Midwest region, United States), sexual segregation may inhibit goals to limit population density. Population sex ratios may be altered by hunting due to spatial segregation by the sexes. In high density populations, unbalanced populations skewed toward females will seldom increase productivity because of increased female-female competition (McCullough et al. 1989).

Although habitat use was similar for sexes, habitat manipulations that consider spatial differences between the sexes could help refine objectives related to population control. Adequate interspersion tends to facilitate spatial separation while allowing both sexes to utilize preferred habitats.

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# APPENDICES

Appendix A. Intraseasonal site fidelity based on 95% cumulative location distributions and percent range-overlap of white-tailed deer at Sand Lake National Wildlife Refuge, South Dakota, 1993-1994.

| Comparison[a] | Deer | Delta | P-value | Overlap (%)[b] |
|---|---|---|---|---|
| 1 | 0180 | -66.9 | < 0.001 | 0 |
| | 0220 | -18.8 | < 0.001 | 63 |
| | 0340 | -78.4 | < 0.001 | 0 |
| | 0370 | -14.7 | < 0.001 | 60 |
| | 0800 | -25.8 | < 0.001 | 50 |
| | 0880 | - 1.7 | 0.067 | 67 |
| | 0930 | -16.1 | < 0.001 | 100 |
| 2 | 0180 | - 6.7 | < 0.001 | 57 |
| | 0220 | -51.0 | < 0.001 | 0 |
| | 0340 | -19.3 | < 0.001 | 30 |
| | 0370 | - 5.6 | 0.002 | 78 |
| | 0800 | -31.0 | < 0.001 | 96 |
| | 0880 | -12.7 | < 0.001 | 96 |
| | 0930 | -15.1 | < 0.001 | 100 |

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[a] Comparisons are: 1) winter 1993/winter 1994 locations, 2) spring 1993/spring 1994 locations.

[b] Percent of first seasons 95% home range overlapped by the second seasons 95% home range.

Appendix B. Interseasonal site fidelity based on 95% cumulative location distributions and percent range-overlap of white-tailed deer at Sand Lake National Wildlife Refuge, South Dakota, 1993-1994.

| Comparison[a] | Deer | Delta | P-value | Overlap (%)[b] |
|---|---|---|---|---|
| 1 | 0020 | -29.4 | < 0.001 | 83 |
| | 0040 | - 6.5 | < 0.001 | 65 |
| | 0050 | -69.1 | < 0.001 | 0 |
| | 0060 | -53.9 | < 0.001 | 0 |
| | 0070 | -15.0 | < 0.001 | 100 |
| | 0100 | - 5.3 | 0.001 | 93 |
| | 0120 | - 2.8 | 0.025 | 61 |
| | 0160 | - 3.9 | 0.006 | 80 |
| | 0180 | - 2.0 | 0.049 | 93 |
| | 0190 | - 0.2 | 0.300 | 85 |
| | 0200 | -44.3 | < 0.001 | 0 |
| | 0220 | -21.1 | < 0.001 | 53 |
| | 0260 | -17.6 | < 0.001 | 34 |
| | 0320 | - 8.6 | < 0.001 | 2 |
| | 0340 | -57.9 | < 0.001 | 4 |
| | 0370 | -16.5 | < 0.001 | 42 |
| | 0800 | -21.0 | < 0.001 | 40 |
| | 0820 | -15.7 | < 0.001 | 66 |
| | 0850 | -49.1 | < 0.001 | 0 |
| | 0880 | - 9.2 | < 0.001 | 61 |
| | 0910 | -14.2 | < 0.001 | 55 |
| | 0930 | - 5.4 | 0.001 | 82 |
| | 1070 | -16.5 | < 0.001 | 47 |
| | 1080 | -16.6 | < 0.001 | 100 |
| 2 | 0010 | -34.8 | < 0.001 | 42 |
| | 0090 | -22.0 | < 0.001 | 92 |
| | 0180 | -52.2 | < 0.001 | 0 |
| | 0210 | -60.0 | < 0.001 | 0 |
| | 0220 | -45.6 | < 0.001 | 0 |
| | 0240 | - 5.6 | 0.002 | 68 |
| | 0270 | -29.3 | < 0.001 | 5 |
| | 0310 | - 5.9 | 0.001 | 95 |
| | 0320 | -11.3 | < 0.001 | 62 |
| | 0340 | -44.5 | < 0.001 | 46 |
| | 0370 | - 5.3 | 0.002 | 68 |
| | 0800 | -25.4 | < 0.001 | 95 |
| | 0820 | - 0.5 | 0.227 | 81 |
| | 0880 | -15.3 | < 0.001 | 94 |
| | 0930 | - 4.5 | 0.006 | 73 |
| 3 | 0180 | -55.2 | < 0.001 | 0 |
| | 0220 | - 4.1 | 0.007 | 65 |

Appendix B. continued.

| Comparison[a] | Deer | Delta | P-value | Overlap (%)[b] |
|---|---|---|---|---|
| | 0340 | -61.9 | < 0.001 | 0 |
| | 0370 | 0.2 | 0.429 | 97 |
| | 0800 | - 8.3 | < 0.001 | 74 |
| | 0880 | - 7.2 | < 0.001 | 66 |
| | 0930 | -23.8 | < 0.001 | 100 |
| 4 | 0180 | - 1.6 | 0.073 | 61 |
| | 0220 | -57.8 | < 0.001 | 0 |
| | 0340 | -72.1 | < 0.001 | 0 |
| | 0370 | -33.6 | < 0.001 | 30 |
| | 0800 | -44.9 | < 0.001 | 96 |
| | 0880 | -18.3 | < 0.001 | 75 |
| | 0930 | -10.6 | < 0.001 | 97 |

[a] Comparisons are: 1) winter 1993/spring 1993 locations, 2) winter 1994/spring 1994 locations, 3) spring 1993/winter 1994 locations, 4) winter 1993/spring 1994 locations.

[b] Percent of first seasons 95% home range overlapped by the second seasons 95% home range.