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Fine-scale habitat use related to crop depredation by female white-tailed deer in an agricultural landscape

Kent Allen Adams
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Kent Allen Adams entitled "Fine-scale habitat use related to crop depredation by female white-tailed deer in an agricultural landscape." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Lisa I. Muller, Major Professor

We have read this thesis and recommend its acceptance:

Frank van Manen, John B. Wilkerson, Craig A. Harper

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Craig A. Harper

Acceptance for the Council:

Anne Mayhew
Vice Provost and Dean of Graduate Studies

(Original signatures are on file with official student records.)

FINE-SCALE HABITAT USE RELATED TO CROP DEPREDATION BY FEMALE WHITE-TAILED DEER IN AN AGRICULTURAL LANDSCAPE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Kent Allen Adams
December 2003

DEDICATION

I dedicate this work to family and friends who have encouraged and nurtured my love for wildlife and the outdoors.

ACKNOWLEDGMENTS

I would like to take this opportunity to extend my thanks to everyone who made this research possible. First, I would like to thank the University of Tennessee Department of Forestry, Wildlife and Fisheries, University of Tennessee SARIF, USDA Hatch Fund, DuPont Crop Protection, and Quality Deer Management Association for funding this research.

I want to express my sincere appreciation to my major professor, Dr. Lisa Muller, for giving me the opportunity to do deer research. She was an excellent advisor and mentor, providing me with guidance, challenges, and a great deal of assistance. She was always accessible, positive, and patient and taught me there is no shame in being a deer bigot.

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I consider the opportunity to be a Chesapeake Farms graduate student a special one. I am grateful to the Chesapeake Farms staff for all their help and hospitality. Dr. Mark Conner was a fine example of a wildlife professional and a surrogate major professor to me. He always had time to discuss my project no matter how busy he was and always gave me sound advice.

Ralph Fleegle and Jeannine Tardiff trained me on the fine art of drop-netting deer. They were always on stand-by to be called to the deer nets and also provided the graduate students with quite a few meals. Ralph gave us invaluable insight about deer movements for trapping and darting set-ups.

George Fahrman cheerfully served as my mechanic and electrician and even handled some "special engineering" on a particularly troublesome GPS collar. Steve Demchyk loaned me a flashlight more than once and put up with trucks zooming by his house in the middle of the night during fawning season. Steve and George also took me out on the Bay for some great oystering and rockfishing. I'm still a land lover, but I definitely enjoyed the trips. David Startt helped out at the deer nets and always knew where to go for any equipment or parts I needed. Bobbi Pippin assisted with some international mailing problems, faxing, and copying and also provided advice on where to eat, get a haircut, workout, and other essential information. The ladies from the kitchen allowed me to be involved in some "taste-testing" from time to time, which I was always happy to do.

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During my work for this project, a graduate student from North Carolina State University also was doing research at Chesapeake Farms. Jonathan Shaw was a great colleague, roommate, and friend. I doubt I have had more deer discussions with anyone else. Since Jon was at the Farms more than I was, he had to endure many calls and emails requesting favors, but never seemed to mind. I am also grateful to the two technicians from NC State, Michael Willaford and James Tomberlin for all their hard work trapping deer. I had the pleasure of working with Dr. Jake Bowman and Jordonna Doughty from the University of Delaware by sharing some study animals. Jake gave me great advice on darting deer, and if not for him, I may have never learned how to insert a vaginal transmitter in a deer (even if the first one didn't go very well).

Finally, I would like to thank my parents, Ken and Patty Adams, for all their sacrifice, devotion, support, and prayers. The "sturdy old" values they instilled in me are what have brought me this far and will continue to be my foundation as I take the next step of my career and my life.

ABSTRACT

The white-tailed deer (*Odocoileus virginianus*) is the most popular game animal in the United States but is also responsible for a large amount of damage to agricultural crops. Understanding how deer use agricultural landscapes on a small scale will facilitate management. Global Positioning System (GPS) telemetry collars were attached to 16 female white-tailed deer at Chesapeake Farms, Kent County, Maryland, during 2 summer growing seasons (10 in 2001 and 6 in 2002). Twelve collars collected usable data and collar success averaged 90 and 86 percent in 2001 and 2002, respectively. Mean adaptive kernel home-range sizes (25.22 ha in 2001 and 39.36 ha in 2002) did not differ between years ($p = 0.14$). Mean core areas (3.12 ha in 2001 and 6.28 ha in 2002) were larger in 2002 ($p = 0.04$).

A habitat selection analysis was performed to determine which habitats were selected more or less than others during the soybean growing season. Habitat use pooled across all deer was different from random in both years ($p < 0.0001$). Habitat use differed among individual deer ($p < 0.0001$). Agricultural crops were among the most selected habitats in both years. In 2001, corn ranked first and soybeans ranked fourth. In 2002, corn and soybeans were selected equally and ranked third. Other important habitats included wooded and early successional areas. Selection of clover ranked comparatively low.

To assess temporal use of selected habitats throughout the growing season, I calculated percentage of daily deer locations occurring in corn fields, soybean fields, clover plots, early successional areas, and wooded areas. Deer use of natural cover and

food sources declined as use of crops increased. Temporal use patterns of some habitats changed between 2001 and 2002, which was likely related to a drought the second year.

Reducing deer damage to agricultural crops while maintaining a healthy deer population requires an integrated strategy that incorporates both deer harvest and habitat management. Considering deer use of an agricultural landscape on a small scale will assist managers in abating damage and providing quality deer hunting opportunities.

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CHAPTER I

INTRODUCTION

The largest white-tailed deer and the most productive populations are frequently found in agricultural areas (Miller et al. 2003). Deer use of farmlands is expected but can result in an unacceptably high level of damage (Storm et al. 1995). White-tailed deer are the leading wildlife species associated with damage to agricultural crops in the United States (Conover and Decker 1991, Conover 1994, Conover 1998). The problem of deer damage to crops has been well documented (Matschke et al. 1984, Garrison and Lewis 1987, Vecellio et al. 1994, Conner and Forney 1997). However, deer in agricultural lands also provide benefits to landowners through hunting, hunting leases, and non-consumptive values. Hunting can increase landowner tolerance of wildlife damage by offsetting costs either through intangible or monetary values (Conover 2001). The challenge for managers is to reduce damage while still providing deer for recreational activities (Campa et al. 1997). More research is needed to identify strategies that allow abundant wildlife and profitable agriculture to coexist (Conover 1994).

Effective deer management requires an understanding of how deer use agricultural landscapes on a small scale. Deer damage evaluations should consider the spatial arrangement of crop fields and surrounding habitat and fine-scaled movements. For example, depredation of soybean crops often only occurs in small portions of a typical soybean field (Garrison and Lewis 1987), with most depredation occurring along the field edge (Matschke et al. 1984). Deer damage to individual fields is influenced not only by deer densities but also the quality of the habitat surrounding agricultural fields

(Campa et al. 1997). Vecellio et al. (1994) suggested surrounding land use could affect feeding intensity. Tardiff et al. (1999) found deer did not select for agricultural crops when high-quality forage surrounded the fields. In order to manage habitat to curtail deer damage, detailed knowledge of how deer utilize agricultural systems is necessary. If landscape features that predispose a field to relatively greater damage can be identified, farmers can make informed decisions to alter cropping activities in that field (Campa et al. 1997). Changes in production practices, such as planting crops that are less palatable to wildlife in high damage areas, could substantially alter the overall amount of losses from wildlife depredation (Wywialowski 1996).

Deer activity and movements are directly related to food availability, and production crops serve as the primary food sources in agricultural ecosystems. Garrison and Lewis (1987) found that timing of soybean browsing affected the level of damage based on growth stage of the plants. As soybean plants developed, browsing intensity declined. VerCauteren and Hygnstrom (1998) suggested that deer respond to changes in corn phenology. Understanding crop use on a temporal scale can provide insight on both habitat and deer management options for damage reduction.

My study is the initial step in a comprehensive project incorporating deer movements and habitat use, precision agriculture, and remote sensing techniques to assess deer damage to agriculture objectively and efficiently. The overall objective of my study was to investigate deer use of an agricultural system to facilitate management of deer damage. Specifically, I wanted to (1) describe deer home ranges and habitat selection in a fragmented agricultural landscape and (2) describe temporal changes in deer use of agricultural fields and other important habitats.

CHAPTER II

LITERATURE REVIEW

Deer Damage to Agriculture

Agriculture and deer hunting both are economically important in the Mid-Atlantic Coastal Plain. Annual revenues generated by agriculture and deer hunting are $50 million and $2.2 million, respectively, in Kent County, Maryland, where 73% of the land area is cropland (Conner and Forney 1997). White-tailed deer are highly adapted to agricultural landscapes where production crops, such as soybeans, corn, and alfalfa, provide abundant and high-quality food sources. Deer thrive in these areas, and their impacts on agricultural systems are substantial. White-tailed deer are the leading species associated with wildlife damage to crops (Conover 1994). Deer also provide hunting opportunities and aesthetic values. A wildlife species may provide both positive and negative values based upon the ways it impacts people (Conover 1997). Deer populations in agricultural landscapes exemplify this situation and present considerable challenges for managers.

Reducing deer damage requires reducing deer numbers (Matschke et al. 1984). Although other damage reduction options exist, their effectiveness is limited when deer are overabundant. Hunting and trapping are the most cost-effective methods available to reduce wildlife populations, and hunting is most commonly used to manage ungulates (Conover 2001). In a 1978 survey of southeastern wildlife resource agencies, antlerless deer harvest was the most successful damage control measure (Moore and Folk 1978). In

1987, 90 percent of wildlife agencies reported they manipulated hunting seasons and bag limits to alleviate damage caused by wildlife (Conover and Decker 1991).

The preferred approach to alleviate deer damage is to maintain deer populations within levels of landowner tolerance by managing annual deer harvest (Erickson and Giessman 1989), specifically, harvest of antlerless deer. However, hunter preference for antlered males can protect females from high rates of hunter-induced mortality (Nixon et al. 2001). Therefore, an adequate doe harvest on private lands requires a high degree of landowner cooperation (Erickson and Giessman 1989) and often is difficult to achieve. Many states provide crop damage assistance programs to augment antlerless harvest (Erickson and Giessman 1989, McNew and Curtis 1997). Damage assistance programs can be controversial because of conflicting opinions of involved stakeholders, difficulties in objectively measuring damage, and difficulty determining unreasonable damage levels (Erickson and Geissman 1989, Irby et al. 1996).

Damage may not always be strictly related to density. Just a few deer may be a problem when local habitat quality is poor (Campa et al. 1997). Shope (1970) found damage by a few deer can exceed economically tolerable limits. Although crop damage increases with deer density, intense damage usually is associated with groups of deer congregating in small croplands (Vecellio et al 1994). Conner and Forney (1997) reported deer reduced corn and soybean profits in certain heavily used areas by an average of $115 per acre at Chesapeake Farms, Maryland, even under a liberal doe harvest management strategy. Deer movements and use of surrounding habitat can greatly affect the amount of damage to agriculture (Miller et al. 2003). Vecellio et al. (1994) suggested woodlot size, surrounding land uses, habitat interspersion, and deer movement among habitats affect feeding intensity in crop fields. Vercauteren and Hygnstrom (1994) found extrinsic forces, such as changes in weather, food availability, and vegetation structure, triggered deer movements within highly fragmented agricultural landscapes.

Habitat management may be a viable option for reducing local deer damage to crops. Campa et al. (1997) suggested planting valuable crops away from wooded areas and improving habitats away from agricultural areas. Planting agricultural fields that are located in areas predisposed to high damage levels with a crop that is not preferred by deer, such as cotton or tobacco, or with an inexpensive food plot forage may prevent large losses for farmers.

Deer Biology and Behavior

The basic social organization in female white-tailed deer consists of a family group comprised of a matriarch, several generations of her daughters, and their fawns (Hawkins and Klimstra 1970). Closely related philopatric female groups have familiarity with food and cover resources and a better ability to defend prime habitat important for neonatal survival (Ozoga et al. 1982). Female dispersal from the group is rare, and young females establish home ranges that overlap with those of their mothers (Ozoga et al. 1982, Mathews and Porter 1993). Mathews (1989) likened this social structure to the pattern of rose petals.

Home-range size varies by sex and age of the individual and by habitat and season (Miller et al. 2003). Ranges are normally smallest in summer when food resources are abundant, and adult females exhibit high site fidelity to these areas (Nixon et al. 1991). Home-range size probably is inversely related to habitat diversity (Loft et al. 1984).

During summer, social groups of deer in the Adirondack Mountains of New York existed in geographically distinct matriarchal groups with overlapping home ranges of social group members (Aycrigg and Porter 1997). McNulty et al. (1997) reported that this social structure and philopatry to seasonal home ranges could provide options for localized management. By targeting specific geographic areas to remove entire social groups, pockets of persistently low deer density could be created in forested environments. However, social group removal likely is impractical in agricultural environments where overall deer densities are greater, cover is limited, and does quickly occupy available fawning habitat.

Deer spend more time feeding than any other activity (Michael 1970). They prefer to eat a variety of plants and are less selective when forage abundance is high (Mooty et al. 1987, Weckerly and Kennedy 1992). Seasonal shifts in centers of activity that do not involve significant changes in range boundaries usually are related to food availability (Marchinton and Hirth 1984). Cropping activities heavily impact food availability in many agricultural ecosystems. Crop emergence and harvest cause dramatic changes in resource availability and may alter habitat use by deer substantially. Growth stages of certain crops also may affect deer use based on plant development and palatability. For example, Vercauteren and Hygnstrom (1998) found deer use of corn increased at the tasseling-silking stage. In fragmented agricultural landscapes where cover is limited, corn may also be an important source of cover, especially during the latter third of the growing season (Vercauteren and Hygnstrom 1998).

Global Positioning System Telemetry

Global positioning system (GPS) telemetry collars offer the possibility to study habitat selection at temporal and spatial scales difficult to achieve with conventional telemetry (Dussault et al. 2001). GPS-based telemetry systems can obtain animal locations over a large geographic area with great accuracy and precision, operate 24 hours a day, operate in a wide range of conditions with little operator or equipment error, and can be cost-effective (Rempel et al. 1995). Di Orio et al. (2003) reported 99 and 93 percent average fix success and 14 m and 16 m average positional error, respectively, for 2 brands of GPS telemetry collars in various wooded habitats. Per individual animal, GPS telemetry is more expensive than conventional VHF telemetry; however, the cost per location may be dramatically lower for GPS-based systems (Rodgers and Anson 1994).

Although GPS technology has many advantages, biases remain (Bowman et al. 2000). Habitat use interpretation is confounded because the probability of obtaining a 3-dimensional location (3-D) varies in time and space. Moen et al. (1996) found that moose behavior and habitat selection (e.g., amount of canopy cover) affected GPS collar performance. Di Orio et al. (2003) reported GPS collar fix success was negatively related to basal area compared among several wooded habitat types, and fix quality decreased as canopy-closure increased. Bowman et al. (2000) had less success obtaining location fixes from bedded deer, which could bias data sets toward active deer locations, resulting in under-representation of bedding sites in habitat analyses. Two-dimensional (2-D) location accuracy relies on the accuracy of GPS antenna altitude estimates (Moen et al.

1997). The greater the error in estimated collar altitude, the greater the influence of horizontal dilution of precision (HDOP) on accuracy (Dussault et al. 2001).

Global positioning system telemetry collars are well suited to study habitat use by deer in the Mid-Atlantic Coastal Plain. The accuracy required to locate a deer in a small field only can be achieved consistently with GPS telemetry. Vercauteren and Hygnstrom (1998) reported reduced movements by does in an agricultural landscape that were undetectable by VHF telemetry. The large volume of accurate locations that can be collected at regular intervals by GPS collars is ideal for determining fine-scale movements. Fix success and quality are reduced in wooded areas. Wooded cover generally is sparse in intensive agricultural landscapes, which should result in improved collar performance overall. However, use of wooded areas by collared animals may be underestimated due to the sampling bias (Di Orio et al. 2003). The terrain in the Mid-Atlantic Coastal Plain is relatively flat, providing optimal conditions for accurate 2-D locations. Confidence in the accuracy of 2-D locations may help alleviate a potential bias toward 3-D locations when deer are active. Much feeding activity in fields takes place at night when deer feel more secure in areas with little cover, and deer are more likely to move farther from the field edge. Collecting objective field data with VHF telemetry presents many logistical challenges (e.g., nighttime telemetry), that do not exist with GPS telemetry.

Habitat Selection

Almost all methods of assessing resource selection by wildlife compare habitat use with some measure of habitat availability (Aebischer et al. 1993). The definition of which habitats are available to an animal can substantially affect the analysis (Johnson

1980). Defining habitat availability solely on the basis of the proportion of an area that is covered by a habitat type assumes that all parts of the area are equally available and accessible, and that habitat distribution within the area has no effect. Animals must expend effort to travel among habitats, so the spatial pattern of habitats likely will influence the choices an animal makes (Arthur et al. 1996). That influence is especially evident in a fragmented agricultural landscape, where cover is limited, and the juxtaposition of habitats may affect how deer access crop fields.

Various techniques to determine habitat selection define availability at several spatial scales (Neu et al. 1974, Johnson 1980, Aebischer et al. 1993). Johnson (1980) described resource selection within the home range as third order and selection within a habitat type as fourth order. The small summer home ranges of female white-tailed deer in the presence of high-quality food sources and the social influences governing home-range spatial arrangement make defining habitat availability difficult. Arthur et al. (1996) described a technique for defining availability at local scales based on location sequences. Using the animal's previous location to define habitat availability for the next location is less likely to violate assumptions regarding equally available habitats throughout the area (Arthur et al. 1996). Moreover, defining habitat availability separately for each observation of habitat use eliminates the concern of autocorrelation among locations that were collected over short time intervals (Arthur et al. 1996).

CHAPTER III

METHODS

Study Area

My study was conducted during 2001 and 2002 on Chesapeake Farms (Figure 1) located outside of Chestertown (39° 13' N, 76° 03' W) in Kent County, Maryland. Mean annual temperature is approximately 13-16°C. Mean annual precipitation is about 102-127 cm (National Climatic Data Center 2003). Chesapeake Farms is a 1,330-ha agricultural development and wildlife management demonstration area operated by DuPont Agricultural Products. The area was approximately 50% forested, 33% tillable, 14% managed wildlife habitat, and 3% impoundments. Trapping efforts were focused on a 300-ha section of the farm where most of the production agriculture was concentrated (Figures 2 and 3). That area was composed of about 70% crop fields, 17% woods, 10% early successional areas, and 3% ponds. Two tidal creeks formed the eastern and western boundaries, joining into the Chesapeake Bay headwaters at the southern portion to form a peninsula. The creeks were not strict barriers to deer movements, but generally deer did not cross them in their normal movements.

The forested habitats were mostly mature hardwoods composed of mixed oaks (*Quercus spp.)*, sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), yellow poplar (*Liriodendron tulipifera*), and sycamore (*Platanus occidentalis*) with an understory of Japanese grass (*Microstegium vimineum*), greenbrier (*Smilax spp*.), multiflora rose (*Rosa multiflora*), and highbush blueberry (*Vaccinium*

Figure 1. Location of Chesapeake Farms, Kent County, Maryland

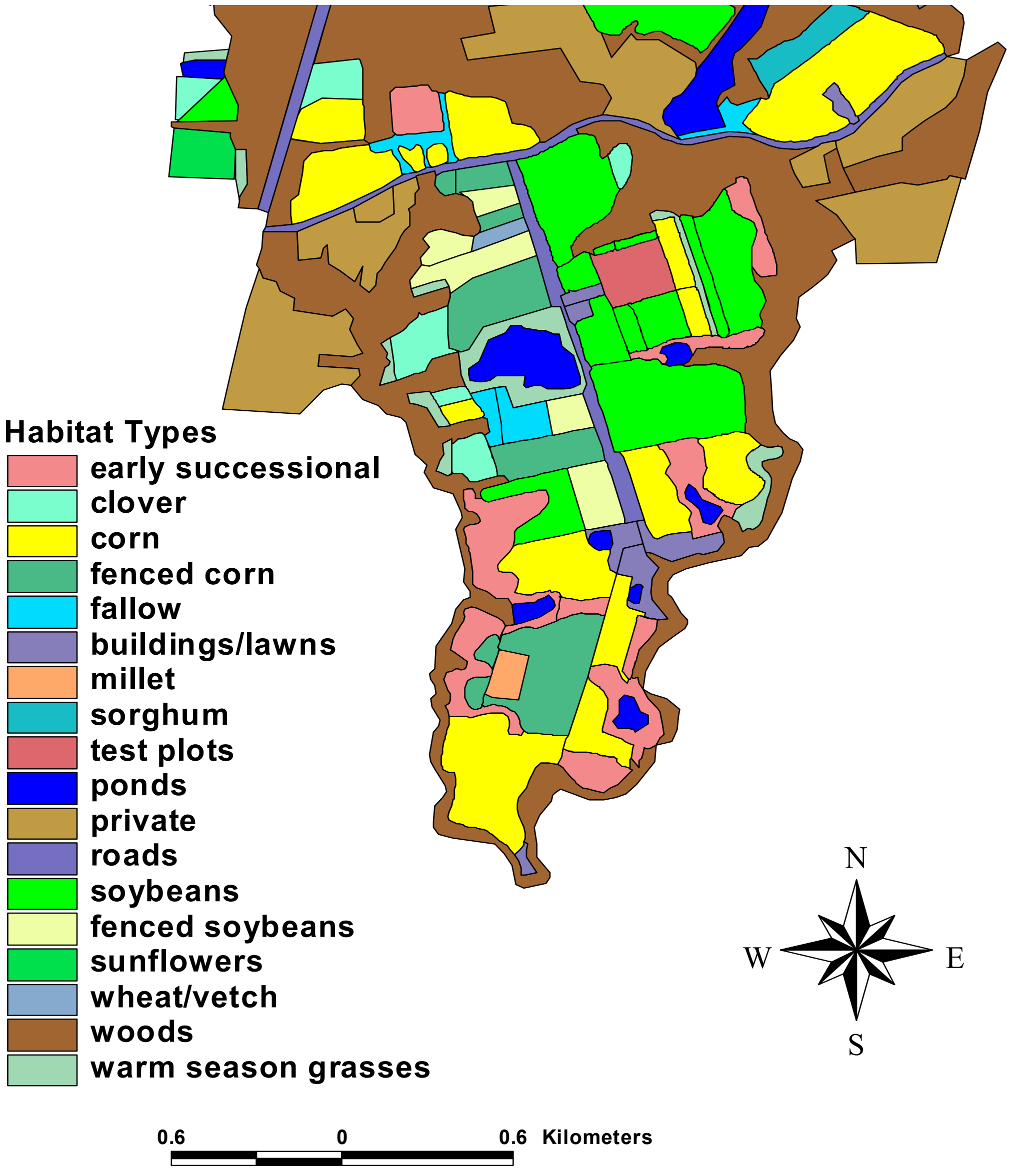

Figure 2. Habitat classification for Chesapeake Farms, Kent County, Maryland during 2001.

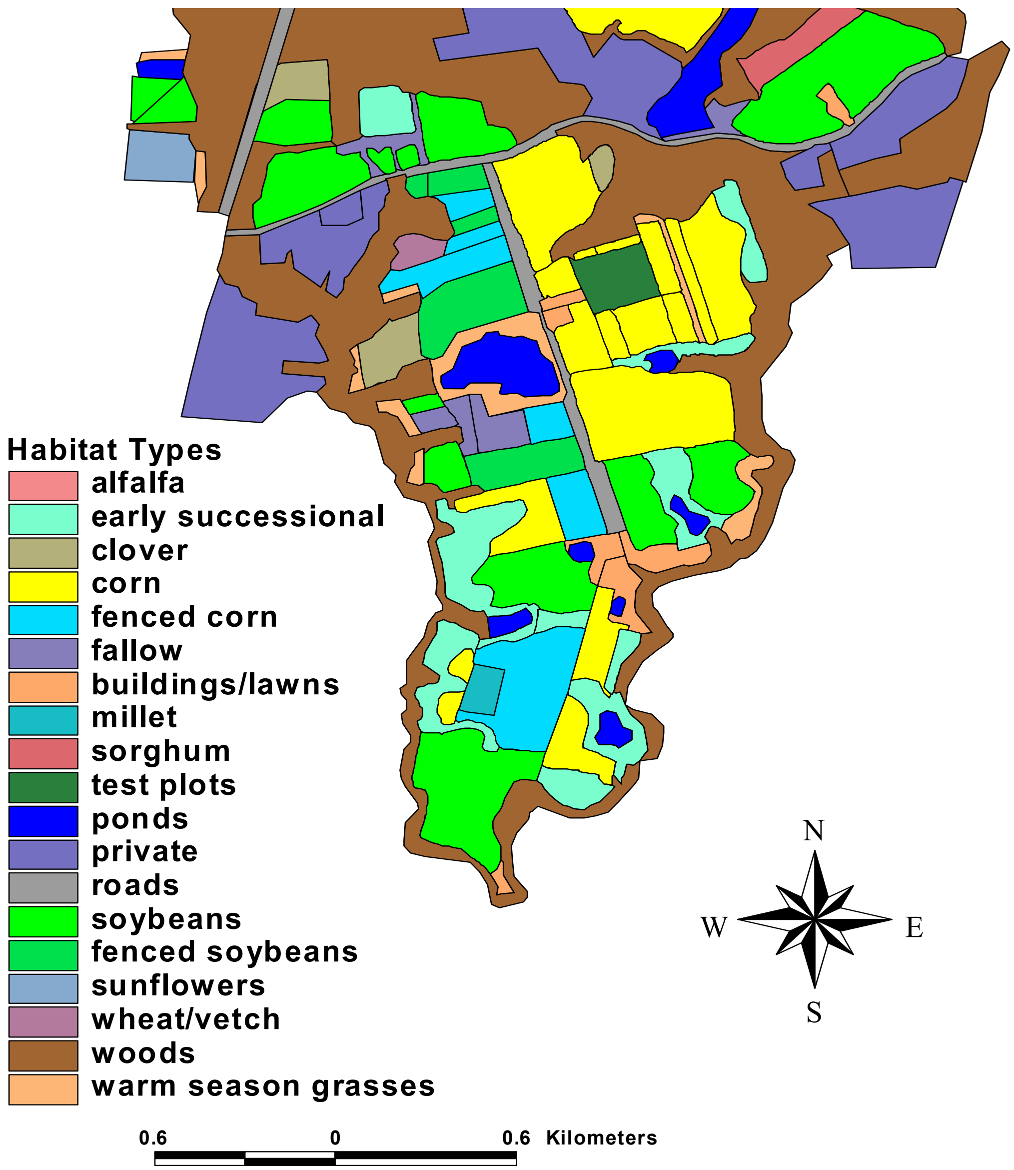

Figure 3. Habitat classification for Chesapeake Farms, Kent County, Maryland during 2002.

corymbosum) (Rosenberry 1997). Some of the low-lying wooded areas consisted of marshes dominated by giant reed (*Phragmites communis*). Over 50% of the tillable land Figure 1. Location of Chesapeake Farms, Kent County, Maryland, was classified as prime agricultural soils. Corn and soybeans were the primary production crops.

In addition to production crops, a variety of wildlife foods were grown, including clover, sunflowers, Japanese millet, grain sorghum, winter wheat, and rye. Natural foods and cover were promoted through burning, mowing, and herbicide use. The most common species found in the early successional areas were multiflora rose (*Rosa multiflora*), brambles (*Rubus spp*.), wild grape (*Vitis spp*.), and Japanese honeysuckle (*Lonicera japonica*). Warm-season grass mixtures included big bluestem (*Andropogon gerardii*), little bluestem (*Schyzachyrium scoparius*), switchgrass (*Panicum virgatum*), and indiangrass (*Sorghastrum nutans*). Fallow fields were predominantly perennial cool-season grasses, such as tall fescue (*Festuca arundinacea*) and orchardgrass (*Dactylis glomerata*), and various forbs.

Chesapeake Farms has practiced Quality Deer Management (QDM) since 1994 (Miller and Marchinton 1995). Approximately 5 does are harvested for every buck (Rosenberry 1997), and the majority of the harvest occurs during a 2-week shotgun season in late November and early December. The deer herd is maintained with a balanced age structure and sex ratio of approximately 1 buck to 1.5 does (J. Shaw, North Carolina State University, unpublished data). Rosenberry (1997) reported a deer density of approximately 50 deer/km^2. Wickham (1993) estimated reproduction at 1.3 fawns per adult doe and fawn survival at 82 percent. Since those estimates were established, the overall deer density has been reduced to approximately 25-30 deer/km^2 (Conner, person. commun.).

Habitat Classification

Habitats were classified in 2 ways. Chesapeake Farms personnel delineated most of the study area by walking habitat perimeters with hand-held GPS receivers and transferring the information into a geographic information systems (GIS; ArcView®GIS Version 3.2, ESRI, Redlands, California, USA). Gaps in these data layers and (e.g., inaccessible areas) were digitized in a GIS using 1:24,000 U.S. Geological Survey 7.5-min digital orthographic quadrangles (DOQ) with 1-m resolution.

Habitat types consisted of fields that were either fallow, planted as wildlife food plots, native warm-season grasses, or under active cropping with corn or soybeans. Areas beyond the study site, where no habitat information was available but were considered usable by deer, were classified as "private lands." Both oldfields and managed thickets were grouped as early successional habitat. The composition of the wooded areas was fairly uniform, and no attempt was made to classify specific forest types. Buildings and structures and surrounding lawns were classified as "buildings/lawn." Portions of the crop fields were used as demonstration areas or winter wildlife food plots. These designated areas were fenced with 2 separate strands of electrified nylon/wire material during summer to prevent deer access. Although not entirely deer-proof, these fences can substantially reduce deer damage. Therefore, I classified them as unique types ("fenced corn" or "fenced soybeans") for the habitat use analysis. Fenced areas where very small test plots of various crops were grown were classified as "plots." For the temporal description of habitat use, fenced and unfenced crops were not differentiated, because availability was not considered. If a deer used a fenced field, I assumed that the fence was not a deterrent to that particular animal, and separate classification was not required.

Animal Capture

From February through May of 2001 and 2002, deer were captured using both drop nets (Conner et al. 1987) and darting. Deer captured with drop nets were immobilized with approximately 2.2 mg/kg xylazine (Cervizine®, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA) injected intramuscularly (IM) and reversed with 0.125 mg/kg yohimbine IM (Antagonil®, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA). Deer were darted with 2 ml telemetry darts (Pneu-dart, Inc., Williamsport, Pennsylvania, USA) with approximately 4.5 mg/kg Telazol® (Fort Dodge Animal Health, Fort Dodge, Iowa, USA) and approximately 3.2 mg/kg xylazine. The dart rifle was powered by compressed air (Dan-Inject, Wildlife Pharmaceuticals, Fort Collins, Colorado, USA). Darted deer were reversed with 0.125 mg/kg yohimbine injected half intravenously (IV) and half IM. All captured deer were handled according to protocols approved by the University of Tennessee Institutional Animal Care and Use Committee (The University of Tennessee, IACUC #1022).

Both monel and color-coded cattle ear tags and GPS tracking collars (GPS-2200 Lotek Engineering, Ontario, Canada) were attached to adult (>1.0 yr.) females. Only females were collared, because they are philopatric and primarily responsible for local crop depredation. Deer were aged by tooth wear and replacement when harvested during the hunting season, following the data collection period (Severinghaus 1949). A known-age deer jaw collection obtained from deer tagged as fawns at Chesapeake Farms was referenced to improve the aging technique.

GPS Collars

I programmed collars before deer capture to record locations every 2 hours. Collars were removed after deer were harvested by hunters. Data were downloaded to a computer using a download link unit and software (GPS Host, Lotek Engineering, Ontario, Canada). To improve quality of locations, I discarded 3-D locations with HDOP > 10 and 2-D locations with HDOP > 5. (HDOP is a unitless measure of satellite geometry with increasing error as HDOP increases.) Because Selective Availability (SA), the intentional degradation of satellite signals by the United States Department of Defense, had been discontinued prior to data collection, I did not differentially correct deer locations. Di Orio et al. (2003) reported that positional error of nondifferential *Lotek* GPS collar fixes taken after SA was discontinued was comparable to that of differentially corrected fixes taken before SA removal. Visual observation of locations plotted on a DOQ map provided anecdotal confirmation that locations were highly accurate. Very few locations occurred in areas where deer presence seemed unlikely (e.g., ponds). In one particular area, collared deer were commonly observed close to a pond, but only a few deer locations occurred beyond the pond edge (Figure 4). Of those locations that did fall in the pond, none were more than a few meters beyond the edge. These probably were not erroneous, because water levels were much lower during my study than represented on the DOQ or habitat coverage.

Data Analysis

Home Range Analysis

I imported coordinates of deer locations into ArcView®GIS Version 3.2 (Environmental Systems Research Institute Inc., Redlands, California, USA). I used the

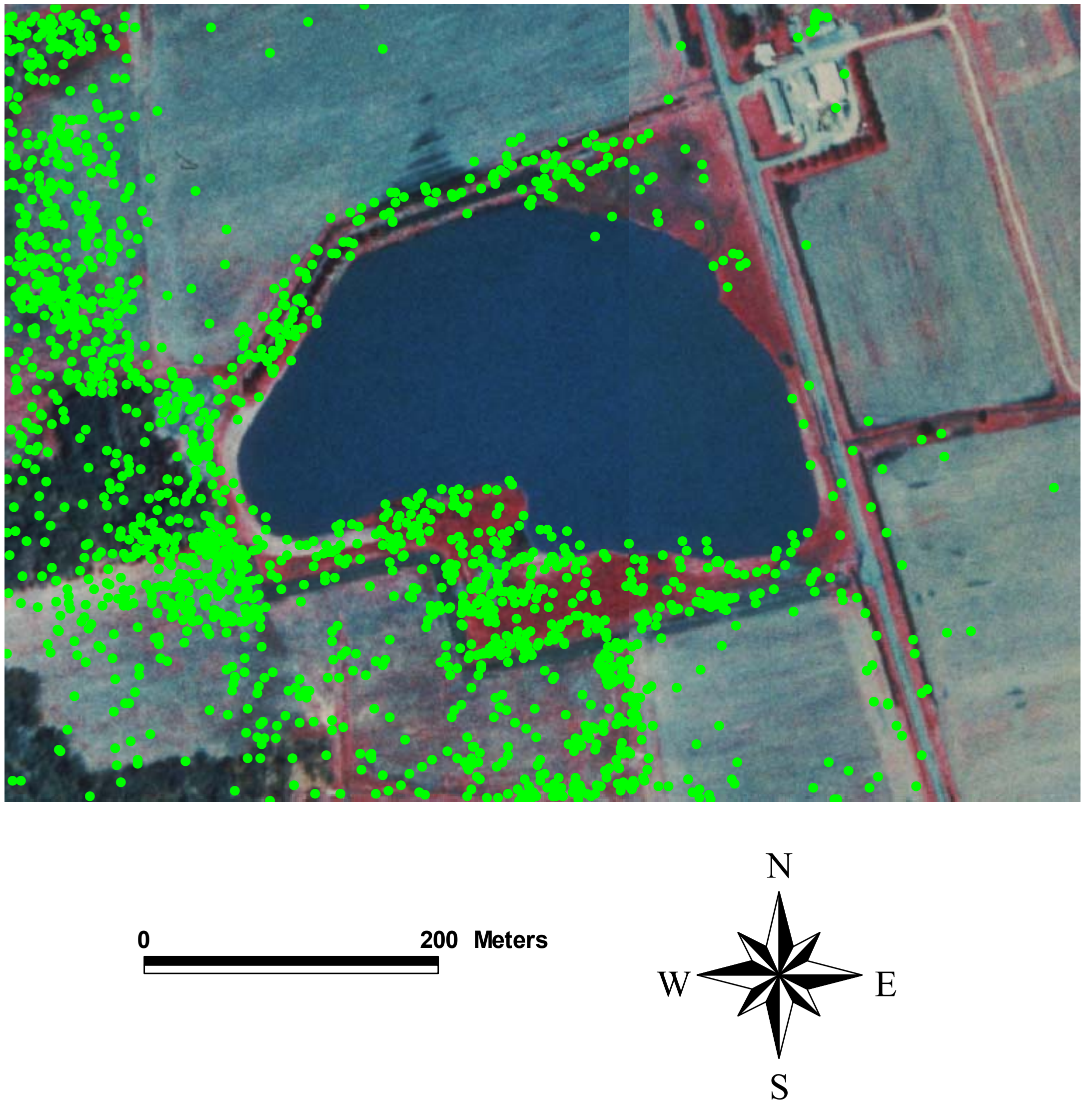

Figure 4. Locations from 3 white-tailed deer obtained by GPS tracking collars during 2001 in and around a common bedding area consisting of warm season grass patches planted on the edge of a large pond at Chesapeake Farms, Kent County, Maryland.

Animal Movement Extension to ArcView® to calculate adaptive kernel home ranges (95 percent) and core areas (50 percent) for each deer (Hooge and Eichenlaub 1997). I determined home-range overlap between pairs of deer by overlaying home-range polygons in ArcView®GIS. A systematic strategy that adequately sampled animal movements throughout the duration of the study and achieved biological independence was more important than determining a time interval between sampling that was statistically independent (Kernohan et al. 2001). Although locations were recorded at a relatively short sampling interval (2 hours), deer are highly mobile species and were physically capable of traveling throughout the entire study area in 2 hours.

Habitat Selection Analysis

The soybean growing season began shortly after soybean emergence and ended just after soybeans reached maturity. At maturity, the leaves turn yellow and drop, concluding the period of green forage availability. I examined habitat selection by deer during the soybean growing season based on a technique described by Arthur et al. (1996). Habitat use was compared to availability by using a circle for each location, centered on the deer's previous location. Some locations were more than 2 hours apart due to fix failures and, therefore, were excluded from the analysis. Circular buffers were centered on each location and then combined with a GIS habitat coverage to define availability of individual habitats for the next location (Figure 5). The circle radius was set to a distance that would encompass 90 percent of subsequent deer locations based on consecutive movement distances. Areas of each available habitat type occurring within each circular buffer were calculated and used to determine proportional availability of

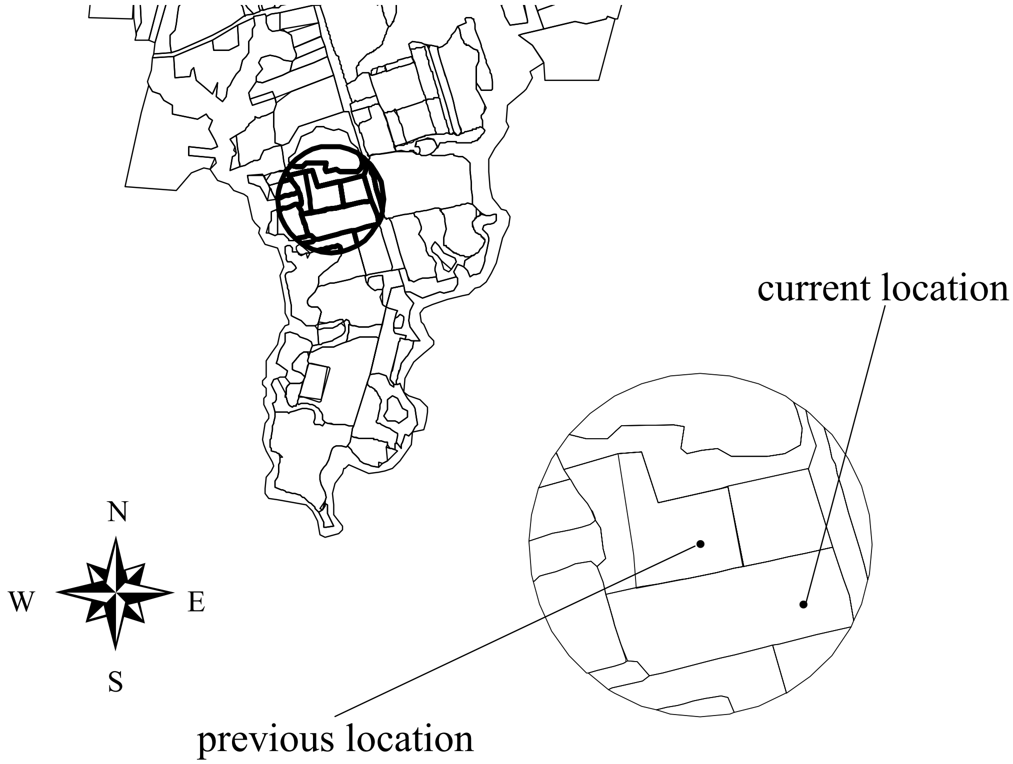

Figure 5. Example of a buffer of habitat availability for 1 white-tailed deer location constructed by centering a circle on the deer's previous location. Buffer size was determined by using a circle radius equal to 90 percent of distances traveled between successive locations every 2 hours (280 m and 326 m for 2001 and 2002, respectively). Deer locations were collected with GPS tracking collars at Chesapeake Farms, Kent County, Maryland in 2001 and 2002.

habitat for each location. That information was paired with the habitat type where the deer was actually found during the next location.

Some buffer circles included areas along the tidal creek borders where habitat coverages did not extend. Because these undefined portions of the buffers included areas beyond water barriers, and because deer almost never occurred beyond these barriers, I excluded them from the availability calculations. The assumptions for this technique were that areas within the buffers were equally available and that movement differences did not occur among adult females.

To characterize habitat selection by deer, I calculated a resource selection index value for each habitat type for each observation based on use and availability of the habitats within each circular buffer. Calculation of the resource selection index was performed based on the following equations (Arthur et al. 1996):

$$\hat{w}_k = \frac{\sum_{t=1}^{D} o_{ik}}{\sum_{t=1}^{D} \frac{A_{ik}}{\sum_{j=1}^{H} A_{ij} b_j}},$$

$$b_k = \frac{\hat{w}_k}{\sum_{j=1}^{H} \hat{w}_j},$$

where *k* indicated one of the 19 possible habitat types (H = 19) which made up the set j. The variable o_{ik} was the proportional use of habitat type *k* at time *I*, which was either 0 or 1. The variable A_{ik} was the proportional availability of type *k* at time l. The variable b_k was the estimated selection index for type *k*, and *D* was the number of times a deer was located. The values of b_j were then determined through iteration. To represent random habitat selection, values for b_j were set equal to 1/19 to solve for the first equation. Then the second equation was used to calculate new values for b_j, which were substituted back into the first equation. Through iteration, the process was repeated until $b_j = w_j$ for all habitat types.

I tested if habitat use was different from random for each year. I determined if deer as a group used habitat selectively and if individual deer differed in selection using a repeated measures analysis of variance (SAS Institute, Cary, North Carolina, USA). If habitat use was selective, I used another repeated measures analysis to test if pairs of habitats were selected more or less than each other to rank resource selection index means.

To further explore the habitat selection analysis, I performed a descriptive analysis to determine what portions of soybean fields deer used, relative to surrounding habitat types. I identified soybean fields that collared deer used in each year and calculated distances from deer locations within those fields to all habitat types that bordered the fields using the Nearest Features extension to ArcView® (Jenness Enterprises Flagstaff, Arizona, USA). I only used deer locations collected after 15 July in both years to ensure that corn was tall enough to provide cover for deer. Then, I generated an equal number of random points within the same soybean fields using the

Random Point Generator extension to ArcView® (Jenness Enterprises Flagstaff, Arizona, USA), and again calculated distances from random locations within the fields to all habitat types that bordered the fields. I compared distances from deer locations to each habitat type with distances from random locations to each habitat type.

Temporal Analysis

I investigated temporal use of certain habitats throughout and beyond the soybean growing season, by calculating the percentage of deer locations per day occurring in 6 habitat categories. Corn and soybeans were of primary interest, because they were the most important production crops and received the most deer damage. Although not a production crop, clover also was considered because of its forage qualities during cool seasons. I also considered early successional habitats because they provide abundant browse, soft mast, and cover. Wooded habitats provided limited browse but were considered because of cover quality.

CHAPTER IV

RESULTS

Collar Performance

Sixteen GPS collars were deployed during my study with 12 collars recording usable data. Ten and 6 does were collared during 2001 and 2002, respectively (Table 1). Average fix success was 90 percent in 2001 and 86 percent in 2002. Of all successful fixes, 53 percent in 2001 and 46 percent in 2002 were 3-D (Table 2). The most common reasons for fix failure, as documented by the collars, were insufficient satellites and antenna problems but varied by collar (Table 2). In 2001 deer died from undetermined causes shortly after the collar was deployed, and I excluded those data from analysis. Another collar during 2001 failed to collect any data because of a faulty GPS unit. A third collar collected data for about 1 month and then malfunctioned for unknown reasons. Two collars in 2002 also failed to collect data; one suffered a damaged antenna cable, and one incurred water damage because bad battery pack seal. The collar failures reduced desired sample sizes during both years of data collection.

Home Range and Movements

Summer home ranges and core areas were calculated for 8 and 4 deer in 2001 and 2002, respectively. Mean core areas ($P = 0.04$) differed between years but home ranges did not ($P = 0.14$; Table 3). Eight pairs of deer had overlapping home ranges in 2001 (Table 4, Figure 6). However, overlapping portions for 2 of the pairs were small. Three pairs of collared deer had overlapping home ranges in 2002 (Table 4, Figure 7). None of the collared deer emigrated while being monitored. One yearling doe traveled

Table 1. Age, capture date, and data collection period for 12 female white-tailed deer fitted with GPS tracking collars at Chesapeake Farms, Kent County, Maryland, during 2001 and 2002.

Deer ID[1]	Deer age at harvest[2]	Capture date	Data collection period
8B	unknown	14 Feb 01	15 Apr 01—11 Oct 2001
9B	2.5	14 Feb 01	15 Apr 01—23 Jun 2001
16B	4.5	28 Feb 01	15 Apr 01—08 Oct 2001
18B	3.5	19 Mar 01	15 Apr 01—10 Oct 2001
30B	4.5	23 Mar 01	15 Apr 01—11 Oct 2001
32B	2.5	05 May 01	06 May 01—11 Oct 2001
33B	unknown	13 May 01	16 May 01—11 Oct 2001
34B	5.5	17 May 01	18 May 01—22 Nov 2001
40B	1.5	04 Apr 02	5 Apr 02—09 Sep 2002
42B	3.5	05 Apr 02	12 May 02—09 Sep 2002
44B	7.5	29 Apr 02	30 Apr 02—26 Sep 2002
45B	3.5	15 May 02	16 May 02—30 Nov 2002

[1]Deer ID was based on cattle tag number and color (B = Blue).

[2]Deer were aged (in years) by tooth wear and replacement in fall following summer data collection (Severinghaus 1949). Deer of unknown age were at least 1.5.

Table 2. Data collection results of 12 GPS telemetry collars deployed on adult female white-tailed deer at Chesapeake Farms, Kent County, Maryland, during 2001 and 2002. Percentages of successful fix attempts, successful fixes that were 3-D, and reasons why failed fix attempts occurred are listed.

Deer ID	**Successful fix**	**3-D fix**	**< 3 satellites**	**Antenna problem**	**Bad almanac**	**High DOP**	**GPS time NA**
30B	96	63	53	7	28	7	5
9B	95	54	74	1	9	14	3
33B	68	45	14	14	22	2	48
16B	93	51	21	66	3	8	2
34B	82	41	76	2	8	6	8
32B	97	56	49	32	6	8	5
18B	97	57	66	0	9	18	8
8B	89	55	45	31	10	6	7
45B	93	43	69	5	0	14	11
40B	73	45	22	71	3	3	1
44B	87	50	18	25	25	3	2
42B	90	44	60	1	7	10	22
Average	88	50	47	21	11	8	10

Table 3. Adaptive kernel summer home range (95 percent) and core area (50 percent) for adult female white-tailed deer at Chesapeake Farms, Kent County, Maryland in 2001 and 2002 as determined from deer locations collected by GPS tracking collars.

Year	Variable	N	Mean (ha)	SE	Minimum (ha)	Maximum (ha)
2001	home range	7	25.22	5.46	9.94	45.91
	core area	7	3.12	0.47	1.97	5.45
2002	home range	4	39.36	6.51	25.18	56.74
	core area	4	6.28	1.59	2.65	10.12

Table 4. Observed adaptive kernel summer home-range overlap between pairs of female white-tailed deer at Chesapeake Farms, Kent County, Maryland in 2001 and 2002. For each pair of deer, percent of deer A's home range overlapped by deer B's home range and percent of deer B's home range overlapped by deer A's home range are given.

Deer A[1]	Deer B[1]	Overlap area[2] (ha)	Percent of A overlapped by B	Percent of B overlapped by A
2001				
16B	18B	10.66	80.57	64.27
16B	30B	12.60	95.17	33.95
16B	32B	4.87	36.80	50.41
18B	30B	12.02	72.48	32.41
18B	32B	5.29	31.91	54.80
18B	8B	0.84	5.08	3.74
30B	32B	7.51	20.24	77.70
32B	8B	0.05	0.48	0.22
2002				
42B	40B	19.42	36.45	28.08
42B	44B	9.99	18.75	41.33
44B	40B	18.46	76.40	26.70

[1]Deer were identified by cattle ear tag number and color (B = Blue)

[2]Overlap was determined by overlaying home-range polygons in ArcView®GIS.

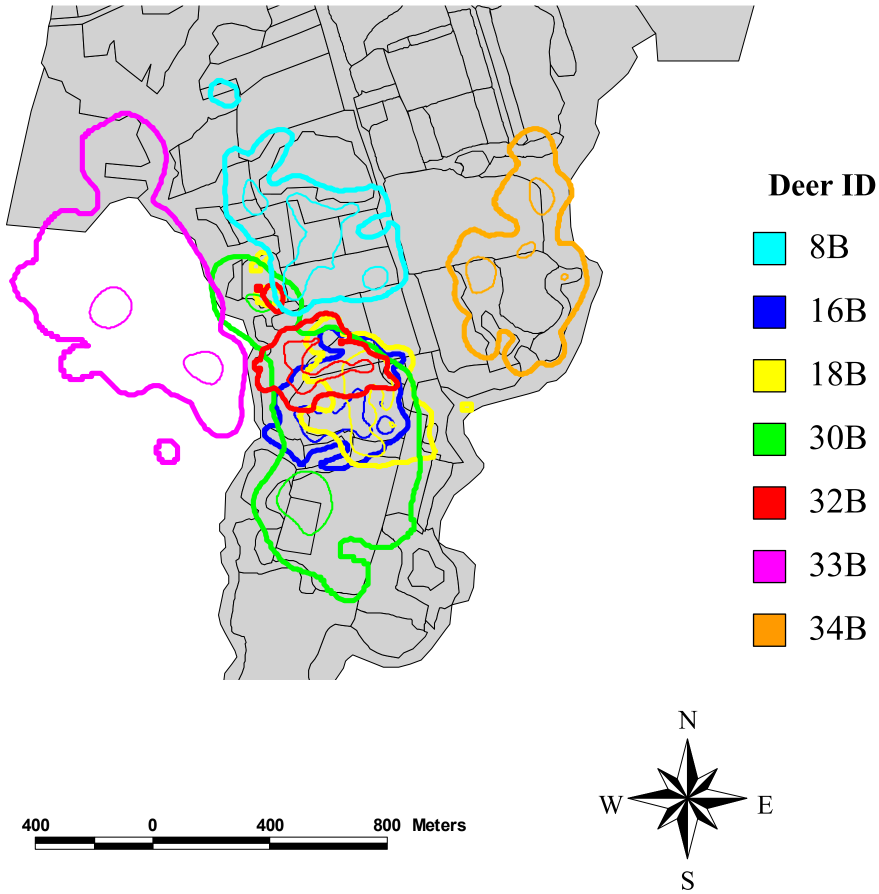

Figure 6. Adaptive kernel home ranges and core areas of 7 female white-tailed deer at Chesapeake Farms, Kent County, Maryland during summer of 2001. Thick lines represent home ranges and thin lines represent core areas. Deer locations were obtained using GPS tracking collars.

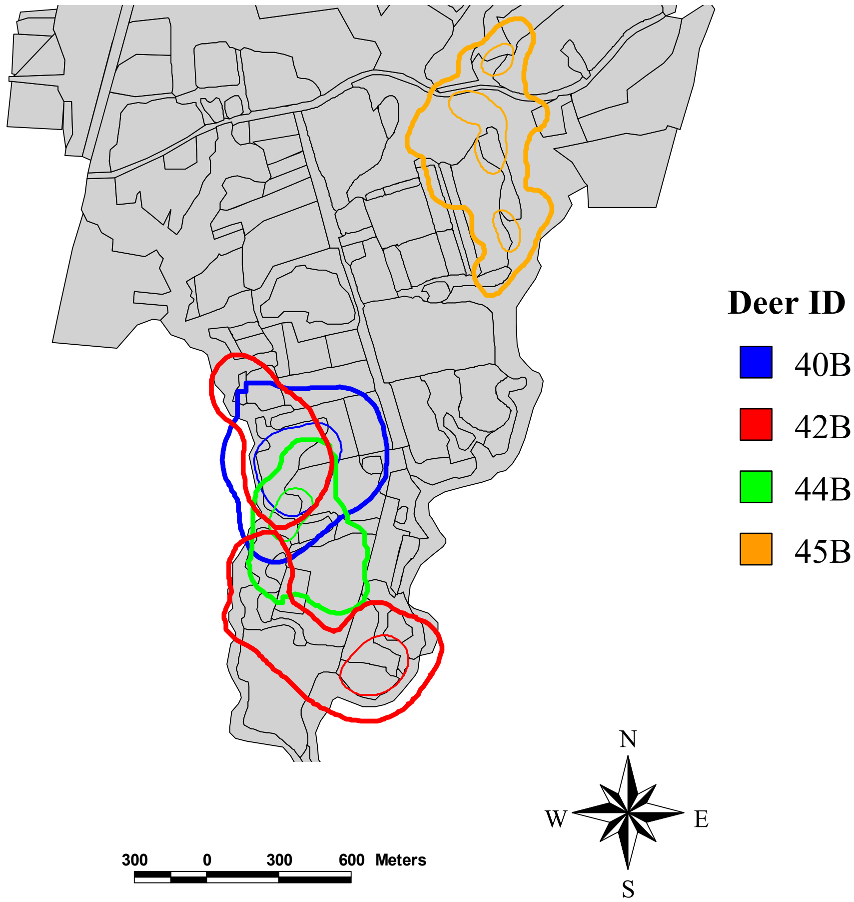

Figure 7. Adaptive kernel home ranges and core areas of 4 female white-tailed deer at Chesapeake Farms, Kent County, Maryland during summer of 2002. Thick lines represent home ranges and thin lines represent core areas. Deer locations were obtained using GPS tracking collars.

approximately 1.5 km outside her normal home range during mid May, remained in that area for about 2 weeks, then returned.

Habitat Selection

Time periods for habitat selection analysis ranged from 21 June through 14 September 2001 and from 29 May through 1 September 2002. These time periods began when soybeans emerged and continued until soybean leaves yellowed. Two of the 7 deer from 2001 with successful GPS collar data were excluded from this analysis; one doe spent most of her time outside the study area, and one reverted to the 4-hour default location interval, rather than the programmed 2-hour interval. During 2002, a similar malfunction required exclusion of 1 deer from this analysis. Therefore, sample sizes for habitat selection were 5 and 3 deer for 2001 and 2002, respectively. Radii of availability buffers were 280 m and 326 m for 2001 and 2002, respectively.

Habitat selection differed among adult female deer during both years ($P < 0.0001$). Habitat selection by adult females also was different from random in both years ($P < 0.0001$). Nineteen habitat types were available for deer use, although some were never or seldom used. Most of those rarely used habitats comprised a small portion of the study area. Corn, early successional areas, wooded areas, and soybeans were some of the most selected habitats during 2001 and 2002 (Tables 5 and 6). Because deer presence on roads likely was incidental, selection of habitats that were used less than roads was not reported.

A descriptive comparison showed that distance to corn appeared to have the most influence on deer location within soybean fields in 2001 (Figure 8). In 2002, wooded

Table 5. Resource selection index values for 5 female white-tailed deer at Chesapeake Farms, Kent County, Maryland during summer of 2001. Resource selection index means were calculated based on 4,393 locations obtained in 2001 with GPS tracking collars.

Habitat	Mean	Standard deviation	Separation index[1]
corn	2.91	1.61	A
early successional	2.18	1.32	B
fenced corn	1.51	1.26	C
soybeans	1.35	1.03	D
woods	0.88	0.88	E
fenced soybeans	0.71	0.75	F
ponds	0.66	0.68	G
buildings/lawns	0.65	0.86	G
fallow	0.59	1.23	H
warm-season grasses	0.26	0.61	I
clover	0.24	0.52	J
roads	0.19	0.34	K

[1]Separation index was determined using a repeated measures analysis of variance to test if resource selection index means differed between pairs of habitats. Resource selection means with the same letter were not different.

Table 6. Resource selection index values for 3 female white-tailed deer at Chesapeake Farms, Kent County, Maryland during summer of 2002. Resource selection index means were calculated based on 2,962 locations obtained from 3 deer in 2002 with GPS tracking collars.

Habitat	Mean	Standard deviation	Separation index[1]
woods	3.16	2.06	A
early successional	2.25	1.31	B
soybeans	1.80	1.38	C
corn	1.76	1.24	C
fenced corn	1.18	1.29	D
ponds	0.58	0.68	E
private	0.29	0.75	F
millet	0.23	0.37	G
fallow	0.19	0.43	H
roads	0.13	0.25	I

[1]Separation index was determined using a repeated measures analysis of variance to test if resource selection index means differed between pairs of habitats. Resource selection means with the same letter were not different.

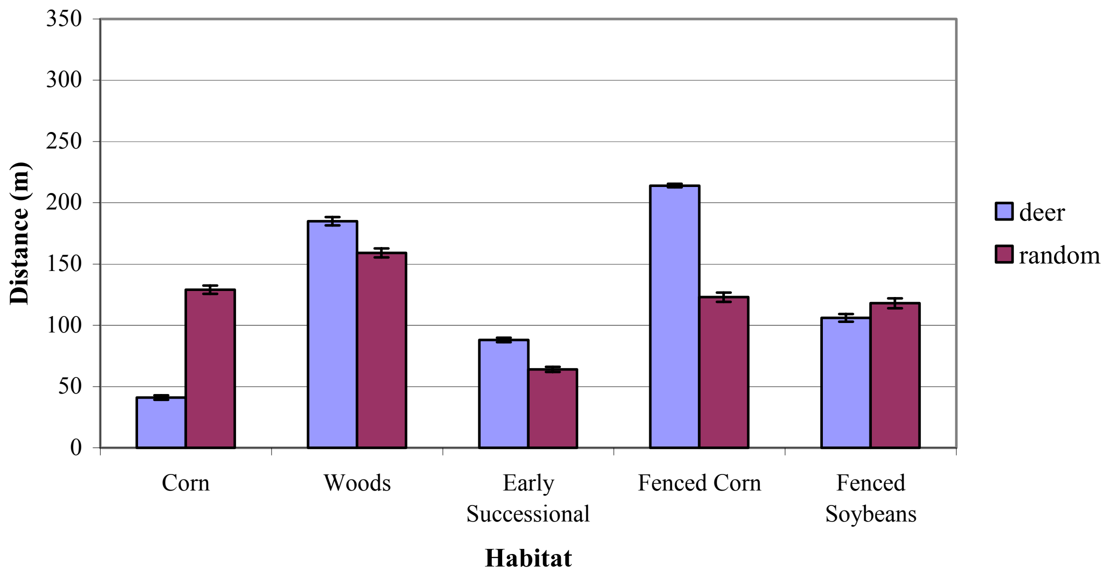

Figure 8. Mean distance from deer locations and random locations in heavily used soybean fields to surrounding habitat types that formed an edge with the soybean fields at Chesapeake Farms, Kent County, Maryland, from 15 July through 10 September 2001.

areas and early successional areas, rather than corn, appeared more important to deer position within soybean fields (Figure 9).

Temporal Use Patterns

Sample sizes for the temporal analysis were 7 and 4 deer during 2001 and 2002, respectively. As with the habitat selection analysis, one deer was excluded, because all of her locations during the analysis period occurred outside the study area, where habitat information was not available. However, the 2 deer that reverted to the 4-hour location schedules were included in this analysis.

The analysis periods for both years began around the time of crop planting. In 2001, soybeans were planted between 27 May and 7 June. Corn was planted from 5-10 May 2001 and harvested between 26 September and 8 October 2001. Temporal analysis was concluded on 11 October 2001, which was prior to soybean harvest. During the planting and growing seasons, monthly precipitation totals were below normal during April, June, and September (National Climatic Data Center 2003). The lack of rainfall in April and early May caused a delay in soybean planting.

In 2002, soybeans were planted from 8-15 May, and corn was planted from 20-27 April. The 2002 analysis period concluded on 9 September because of insufficient fall data. A severe drought occurred in 2002. The estimated Maryland corn harvest was the lowest since 1993, and the estimated soybean harvest was the lowest since 1987 and the lowest per acre yield since 1966 (National Climatic Data Center, 2003).

During May, most deer locations occurred in clover, early successional areas, and wooded areas (Figure 10). By early June, the percentage of daily locations in clover and woods declined, but locations in early successional areas increased. Percentage of

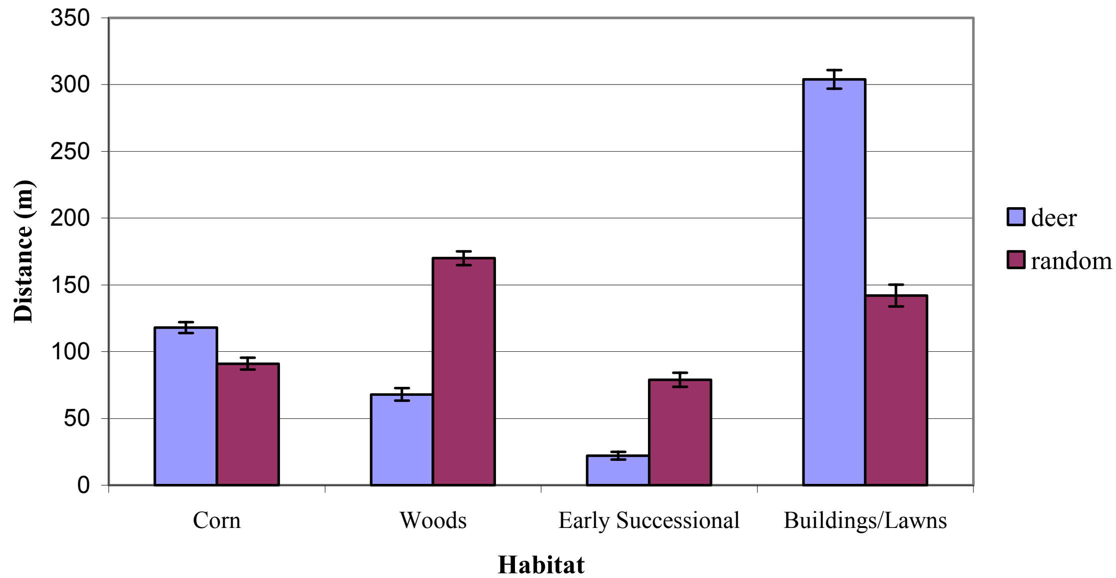

Figure 9. Mean distance from deer locations and random locations in heavily used soybean fields to surrounding habitat types that formed an edge with the soybean fields at Chesapeake Farms, Kent County, Maryland, from 15 July through 1 September 2002.

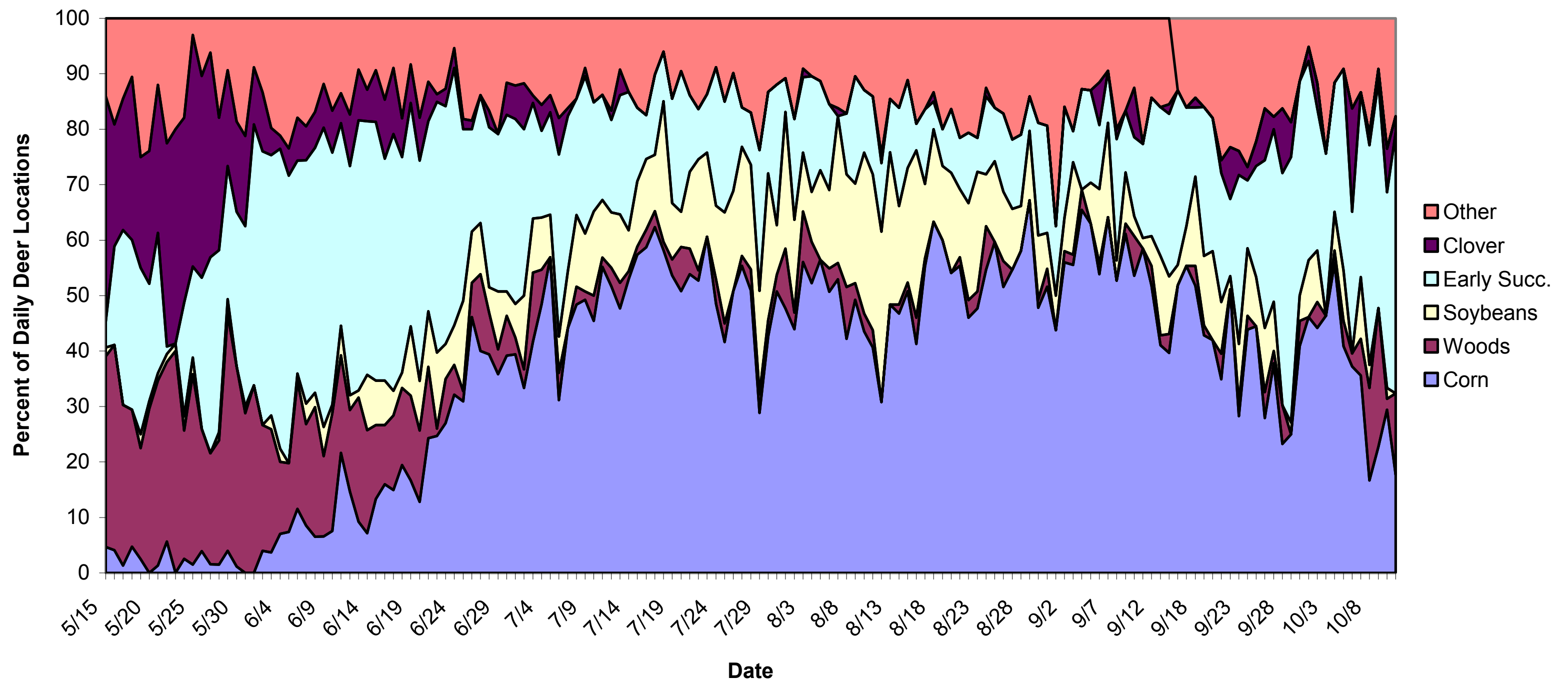

Figure 10. Percentage of daily locations of 6 adult female white-tailed deer occurring in selected habitat types at Chesapeake Farms, Kent County, Maryland, during 2001.

locations in corn fields also began to increase in early June, and by mid-June, use of soybeans began to occur. Use of corn and soybeans both reached a peak in mid-July, which lasted through late August for soybeans and mid-September for corn. During peak use of those crops, over half of daily deer locations occurred in corn, while about 15 to 20 percent occurred in soybeans with large fluctuations between days. During peak use of corn and soybeans, use of clover and wooded areas was rare. Use of early successional areas declined also, but still accounted for about 10 to 15 percent of daily deer locations. When soybean use declined, use of early successional areas increased. Use of early successional areas again increased as corn use declined. Although minimal, use of wooded areas and clover increased at that time.

In 2002, over 90 percent of daily deer locations occurred in wooded and early successional areas during May (Figure 11). Also, some minimal use of clover occurred in May. In early June, use of soybeans, although highly variable between days, accounted for about 10 to 20 percent of daily deer locations which continued throughout summer. Deer began using corn in late June, and from mid July through early August, 30 to 40 percent of deer locations occurred in corn. When corn use increased, use of woods and early successional areas decreased, but about 25 to 35 percent of deer locations still occurred in early successional areas, which continued throughout summer. In mid-August, corn use declined, and use of woods increased.

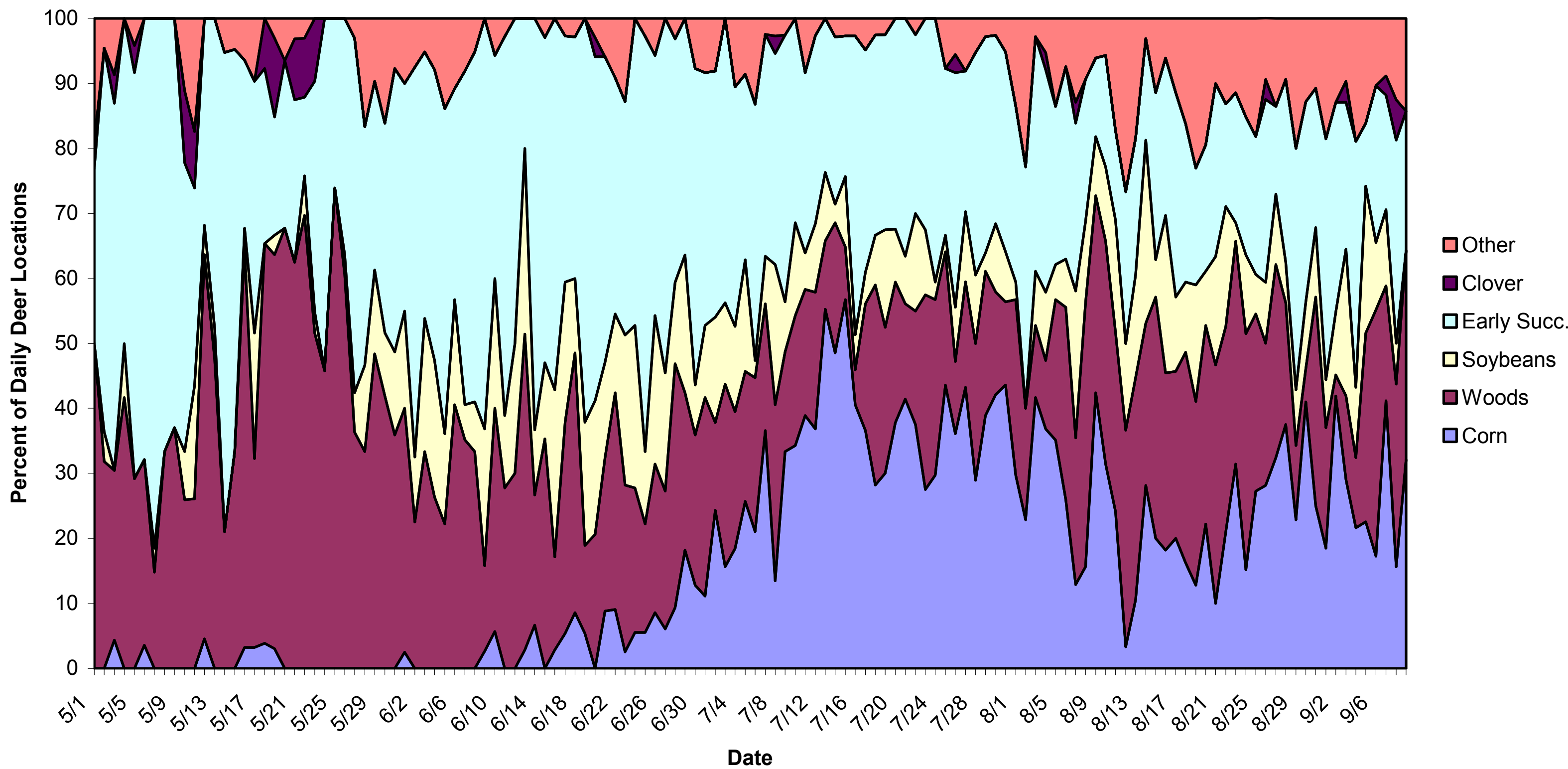

Figure 11. Percentage of daily locations of 4 adult female white-tailed deer occurring in selected habitat types at Chesapeake Farms, Kent County, Maryland, during 2002.

CHAPTER V

DISCUSSION

Because of the high initial cost of GPS collars, obtaining large sample sizes is difficult. Although large amounts of data can be collected for an individual animal, interpretation is limited if only a small proportion of the population is sampled. Nonetheless, detailed data at relatively fine temporal and spatial scales from even a few animals provide valuable insight, particularly for refining population and habitat management. Furthermore, although my samples sizes were relatively low, the adult doe population on the study area was relatively small because of the small and isolated study area (e.g., water barriers). Using a liberal deer density estimate of 30 deer/km^2 on the study area and given the adult sex ratio, I conservatively sampled about 5-10 percent of the adult does on the study area.

Home Range and Movements

The small summer home ranges and core areas of adult female deer at Chesapeake Farms were probably a result of the diversity and interspersion of habitats, the abundance of high quality food sources, and social interactions. Small summer home ranges generally are associated with deer in diverse, productive habitats (Miller et al. 2003). Loft et al. (1984) hypothesized home-range size was inversely related to habitat diversity. Deer also may reduce home-range size to minimize intraspecific encounters as population density increases (Beier and McCullough 1990). Other studies have shown associations between high deer densities and small home ranges (Marchinton and Jeter 1967, Bertrand et al. 1996). In nutrition-rich landscapes with high deer densities and limited cover, competition among does for parturition sites may supercede competition for other resources (Ozaga et al. 1982, Nixon et al. 1991), making social pressure an important factor in determining home-range size and quality for individual deer. However, neither Tierson et al. (1985) nor Kilpatrick et al. (2001) demonstrated increased home-range sizes in response to density reduction.

The deer density on my study area, although fairly high, is much lower than the pre-QDM density. In intensive agricultural landscapes, deer densities would have to be reduced to almost unattainable levels before social interactions do not limit doe home ranges. Therefore, concentrated browsing in specific areas by matriarchal groups might be difficult to stop by density reduction under most harvest plans. The home-range overlap I observed among collared does supports the idea that social pressures influence home-range distribution of does in agricultural landscapes. There seemed to be geographically distinct portions of the study area where different groups of deer established home ranges and remained relatively isolated from each other. The degree of home-range overlap seemed to be associated with capture location. Deer captured at the 2 drop-net sights tended to have overlapping home ranges. Deer captured by dart rifle were more dispersed throughout the study area and did not overlap with netted deer unless they were darted in close proximity to the net sites.

The increase in core area in 2002 might have been associated with dry weather. Eastern Maryland experienced one of the worst droughts in recorded history during summer and fall of 2002, severely reducing the forage production of crops and natural vegetation. Deer probably foraged over larger areas to compensate for lower food quality and availability. Deer also might have expanded their core areas to visit limited water sources. The difference in mean core area may also have been a response to a change in habitat interspersion because of crop rotation between years.

Habitat Selection

Because deer were capable of moving throughout the study area between locations but typically limited their movements to much smaller distances, the analysis technique I used provided a more fine-scale assessment of habitat availability compared with the entire study area. The accuracy and precision of the GPS collars allowed a fine-scale analysis of habitat use. This fine-scale analysis would not be possible with traditional VHF radio telemetry because of greater telemetry error. Using buffer sizes based on 2-hour movements reduced the probability of violating the assumption of equal availability of habitat types within a buffer. By confirming deer presence in the vicinity of the available habitats, it was less likely that social interactions prevented deer use of the available area.

Arthur et al. (1996) warned that the selection index of a rarely available habitat may be estimated less accurately than for other, more commonly available habitats. Also, low fix success by GPS collars in areas of high canopy density may underestimate use of those habitats (Di Orio et al. 2003). Therefore, deer probably used wooded areas more than the habitat analysis indicated, because those areas likely were undersampled.

Although selection differences occurred among individual deer, the analysis technique accounted for that effect. The large number of locations per individual, which produced an equivalent number of habitat selection observations, likely increased the power to detect even subtle differences among individual deer. However, even with individual variation present, habitat affected selection.

Corn was highly selected by deer, because it provided multiple benefits. Corn was used as a food source but also as cover once tall enough to conceal deer. Corn also provided shade during the latter third of the growing season, cool bare ground for more comfortable bedding, and possibly relief from many biting insects (Nixon et al. 1991). Where cover is limited, the emergence of these "artificial woods" during summer gives deer new travel corridors and secure access to areas where they normally would not go during daylight. Judging by the much shorter mean distance from deer locations in soybeans to corn as opposed to mean distance from random locations to corn in 2001, cover from corn provided close proximity to soybeans, and probably contributed to extremely small summer home ranges in 2001.

When deer use corn for cover, edges of preferred crop fields adjacent to corn fields probably incur more damage. For example, the soybean yield in field 43C during 2001 was lower on the south side of the field compared with the north side (Figure 12). The south side was bordered by a corn field, which allowed direct access to the soybeans and provided nearby security cover. The north side was bordered by a fenced corn field, which prevented access to the soybeans for most deer. Darracq (1996) found soybean fields in close proximity to other agricultural fields incurred less deer damage compared to fields in close proximity to wooded areas. That study was conducted in an area where wooded cover was plentiful. Where cover is limited, damage is most likely to occur along any edge between soybean fields and suitable cover.

Deer use of corn fields declined from 2001 to 2002. Corn quality was poor in 2002 because of drought conditions, with yields reduced to one third that of 2001. Corn structure was also poor, with sparse, short stalks and underdeveloped leaves, providing

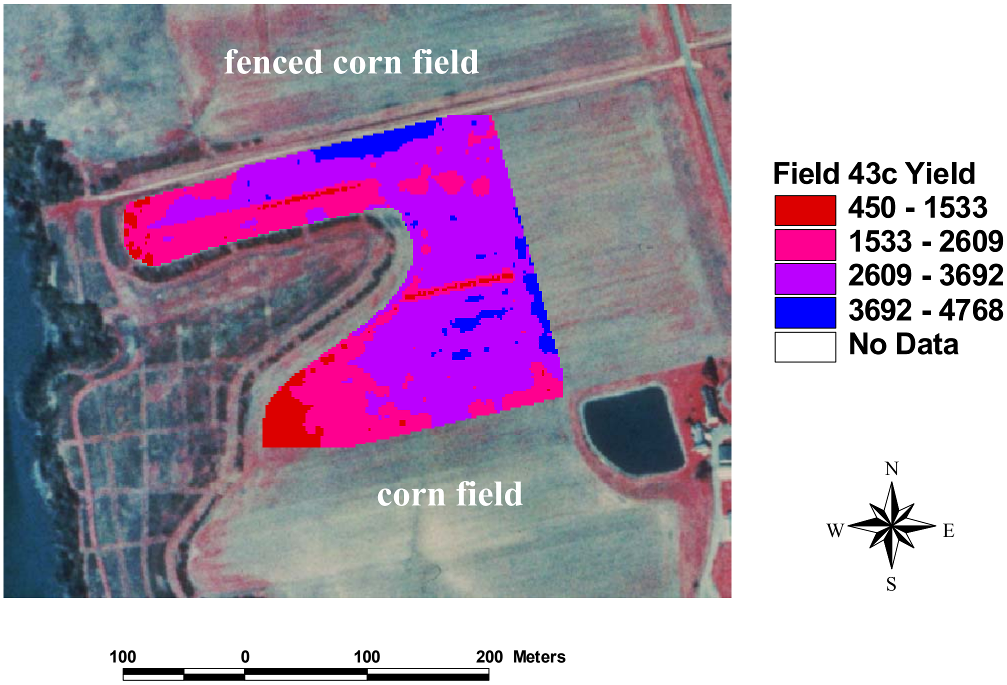

Figure 12. Soybean yield (kg/ha) from field 43C at Chesapeake Farms, Kent County, Maryland, in 2001. Yield and location were recorded at 3-second intervals by monitors mounted on combines. Yield data were interpolated as grids using the Inverse Distance Weighted (IDW) technique with 6 nearest neighbors.

lower quality cover and shade for deer. Concurrently, use of wooded areas increased in 2002, and the distance analysis showed that distance from deer locations in soybeans to early successional and wooded areas was more important than distance to corn. The difference between 2001 and 2002 likely is related to the poor cover quality of corn because of the drought. The drought also likely caused soybean use to increase in 2002. Soybeans are more drought-tolerant than corn and clover and likely provided a better food source for deer compared with other crops and natural vegetation. Consequently, soybean damage by deer may increase during a drought year.

Selection for clover ranked low among available habitats. In 2002, clover patches were stressed because of drought conditions. Although no extended drought occurred in 2001, there was a month-long dry period in late May and early June, which reduced clover quality and production. When the dry period ended, hot temperatures further limited clover production. This was not surprising as clover is a cool-season forage with highest use expected during cooler months, especially where high-quality warm-season forage (e.g., soybeans) is available. In addition, clover patch quality was not uniform over the study area because of varying plot ages. Therefore, availability of quality clover that was attractive to deer was probably overestimated, causing a slight underestimation of clover use.

Structural and yield differences occur between fenced and unfenced corn and soybeans. However, fenced corn and soybean fields were highly to moderately selected habitats. That selection may be due to a few individuals that were not deterred by fences, in combination with an overall small sample size. Deer with the ability to use fenced areas may greatly benefit from reduced competition for resources. If this is a learned behavior passed from dam to offspring, entire social units may be able to exploit such areas.

Early successional habitats comprised a relatively small portion of the study area but remained consistently important in both years of the study. These areas were heavily used because they provided excellent security cover and preferred food sources for deer through most of the summer. Preferred browse (e.g., brambles, honeysuckle, wild grape) was abundant early, and soft mast production lasted from mid-summer through fall, depending on plant species.

Selection for habitats classified as ponds was greater than several other cover types, such as clover, warm-season grasses, and fallow fields. Water levels in ponds were low during summer, and some ponds were completely dry, especially during the drought of 2002. Consequently, deer use of these areas likely occurred at or near the pond edge. Small patches of early successional habitat or warm season grasses surrounded most ponds, providing attractive bedding areas. Also, because the tidal creeks were brackish, the ponds on the study area provided the only fresh water sources for deer during dry weather.

Temporal Use Patterns

The goal of the temporal habitat use analysis was to identify general trends of habitat use over the soybean growing season. This approach complemented the habitat selection analysis, because it identified how different habitat types were used in relation to each other. Temporal analysis is especially important for analyzing crop use because of the dramatic landscape changes that occur during crop development.

The high percentage of deer locations in corn and the timing of peak use likely are a result of the multiple qualities corn provides for deer. The temporal analysis depicts a distinct shift deer made during summer from natural cover, such as wooded areas and thickets, to cornfields. In both years, use of corn by deer increased as the plants matured to heights that provided security cover for deer, and when deer were in soybean fields, they were generally close to a corn edge. At the same time, use of wooded areas and early successional areas decreased dramatically, and they were not important as edges for deer in soybean fields. Overall, corn was used much less during mid-summer in 2002, while use of early successional areas and woods was much greater. The decreased use of corn between years likely was a result of the poor cover value corn provided due to the 2002 drought. These findings are supported by the habitat selection analysis in which selection of corn decreased between years, while selection of woods increased. More support is provided by the lack of importance of corn edge for deer in soybeans during 2002.

The high deer use of early successional areas early in the growing season probably was related to the production of tender and succulent vegetative growth at that time and the cover quality for both the does and their young fawns. Clover plots were used early in the summer before soybeans became available, but clover use quickly became insignificant. The perennial clovers that Chesapeake Farms plants are cool-season legumes and are highly productive and preferred by deer during spring and fall. However, clover becomes less attractive to deer during summer when high soil temperatures make it unproductive.

Deer use of soybeans showed a definite peak in 2001. Soybeans had been growing for over a month before that peak occurred. The delay might be an indication that deer were obtaining adequate nutrition from browse and clover plots during early summer and remained attracted to those areas. Another factor that probably played a role in the timing of this shift was the use of corn as a secure corridor to the otherwise open soybean fields. Deer may have waited for the corn to grow tall enough to serve as security cover before they regularly ventured into the soybean fields. However, other cover was available adjacent to the particular soybean fields that collared deer used most, so access to soybeans was not entirely dictated by corn height. Furthermore, corn had over a month of growth before soybeans became available in 2001, because soybeans were planted late.

In 2002, deer use of soybeans was fairly consistent from the time they became available throughout the summer. The difference in soybean use between years likely was related to the 2002 drought. Although affected, soybeans were the most drought tolerant food source available and were therefore, more important to deer in 2002, as indicated by the habitat selection analysis. However, it is unclear which situation, persistent browsing throughout the growing season or a peak of intense browsing, caused more damage, because I did not directly measure deer-caused yield reduction. Darracq (1996) reported that soybeans were more susceptible to browsing during the second month of the growing season under controlled deer densities and normal or above normal precipitation in South Carolina. Those findings are consistent with my results from 2001 and support the possibility that the drought was responsible for increased soybean use in

2002. However, Garrison and Lewis (1987) found the majority of browsing occurred before the fourth week of soybean growth in Georgia.

CHAPTER VI

MANAGEMENT AND RESEARCH RECOMMENDATIONS

Managing deer numbers to limit crop damage in intensive agricultural areas may require a complex approach. Beier and McCullough (1990) cautioned local deer densities may remain high if only easily accessible areas are hunted. Deer harvest limited to specific areas may cause local overharvest, while female densities remain high over the rest of the area (Nixon et al. 1991). Minimal home ranges exhibited in high-quality agricultural habitats could produce specific areas where adequate deer harvest is difficult to implement. Tardiff (1999) found that use areas of 33 yearling and 12 adult does at Chesapeake Farms did not differ between summer and fall during 1997 and 1998. If does do not expand their home ranges from summer to fall, it may be prudent to consider the deer harvest distribution for reducing isolated areas of severe crop damage.

For my study, deer that were caught at locations separated by relatively small distances (a few hundred meters) used completely different areas and rarely had overlapping home ranges. That type of distribution across a property combined with limited movements may exclude entire social groups from potential harvest. Hunting deer from traditional stand locations that are placed in the more easily hunted areas year after year may create small pockets of overabundant deer even on properties where the overall population is managed below carrying capacity.

Chesapeake Farms implements an aggressive doe harvest, maintaining a balanced sex ratio and age structure. However, certain portions of the property may be under-harvested. Although hunting access is not limited as with large tracts of rugged, forested terrain, areas where most of the crops are grown are difficult to access undetected. Ground hunting is prohibited, and limited wooded cover makes tree stand placement challenging. Consequently, the most agricultural portion of Chesapeake Farms also is the least hunted. Landowners who continue to experience unacceptable deer damage, even after implementing aggressive doe harvest programs, should consider the spatial distribution of the harvest. Other than extreme population reduction (e.g., deer densities under 8 deer/km^2), a versatile harvest approach may be the only option to significantly reduce deer damage. Extreme herd reductions may not be feasible where highly productive deer populations exist and are not usually desirable if quality deer hunting and viewing is valued.

Options for increasing hunter success could be investigated by collecting fine-scale year-round deer data. Monitoring deer through the hunting season would provide insight about how the harvest is distributed across the property in relation to high damage areas. If a window exists during the hunting season when does are more vulnerable to hunting, landowners could increase hunting effort at that time. Effects of hunting pressure on the vulnerability of deer, such as deer becoming nocturnal under heavy pressure, also could be assessed.

In Maryland, damage permits may be used beginning in August and September before the hunting season. However, landowners commonly wait until hunting season to supplement their doe harvest. Using damage permits early should improve harvest success. Deer are generally less cautious and are on a predictable feeding pattern this time of year, providing good opportunities to successfully harvest deer that may otherwise be difficult to hunt by firearms season. Furthermore, during late summer and early fall, deer remain in the vicinity of where they damage crops. Focusing harvest efforts in the specific sections that receive the heaviest damage should allow a manager to lower local deer densities where a reduction is most needed. The ability to easily distinguish mature does from fawns at that time of year provides another advantage. Fewer shot opportunities will be lost if a quick field assessment of an antlerless deer is possible.

Agricultural crops were important habitat types for deer at Chesapeake Farms during summer. Employing non-lethal crop damage reduction methods, such as fencing or repellants, without supplying compensatory food sources, may reduce herd fitness and quality. Natural browse quality also will decrease as the available food sources receive more pressure. Habitat quality for other wildlife such as intermediate canopy-nesting songbirds, also will decline (deCalesta 1994). Non-lethal damage controls are difficult and costly to implement on a large scale. If only a portion of crops is protected, remaining crops receive more pressure, particularly if native browse is overexploited. Non-lethal damage reduction methods become less effective as surrounding habitat quality decreases. An adequate deer harvest is necessary in combination with non-lethal damage control methods for an integrated approach to crop damage abatement.

Heaviest crop damage tends to occur on field edges and in fields bordered by woodlands (deCalesta and Schwendeman 1978, Matschke et al. 1984, Vecellio et al. 1994). Certainly, this is true for fields bordered by any suitable deer cover, particularly when cover is limited. A soybean field separated from wooded areas by a cornfield is in position to receive damage, because the corn facilitates access. In areas where corn and soybeans are planted on rotation, large areas should be planted in one crop or the other rather than increasing edge by interspersing small fields of different crops. If crops that are undesirable to deer, such as cotton or tobacco, are grown, they should be planted next to soybean fields to reduce deer access. Careful planning of crop juxtaposition to surrounding habitats can greatly affect local damage intensity. Keeping highly preferred crops away from suitable cover may prevent deer from using them extensively. However, if crops are made less available to deer, other food sources should be supplied for deer, especially if herd health and quality is a concern. Planting fields that have potential for high damage with inexpensive food plot forages, or simply managing them for early successional browse and forbs are both options. Creating attractive areas away from valuable agricultural fields may help reduce browsing intensity, but expectations must be realistic. There is virtually no summer forage that deer prefer more than soybeans.

Although most deer damage occurs on soybean field edges, damage to corn may be a different matter when they use it as cover. Deer do not need to be near the edge of a corn field to feel secure. Therefore, damage may be spread out over a larger area in a corn field. However, because corn has multiple qualities for deer, use of corn is not a good indicator of damage levels. It may be useful to investigate deer activity levels in corn to determine the extent of damage that occurs based on deer presence in corn.

Although agricultural crops were among the most selected habitats, other habitats, particularly early successional areas, also were important to deer. Availability and quality of surrounding habitat seems to affect the timing and intensity of deer use of agricultural crops. Maintaining early successional areas may help reduce deer damage to crops by delaying the onset of crop use or buffering browsing intensity. These brushy thickets and old field patches are relatively inexpensive to establish and maintain with bushhogging, burning, and herbicides. The high preference of early successional habitats emphasizes the importance of managing natural vegetation for deer, particularly in cover-limited landscapes. If habitat management practices had not been used to provide a diverse mix of cover types, crops probably would have received additional damage. A few weeks difference in the onset or duration of heavy browsing could have major impacts on crop yields. The importance of diverse habitat is magnified in a drought year. Drought-resistant crops may incur more browsing if they are the only food source available. Under stressful conditions, plants may be less tolerant of browsing, further reducing already poor yields.

Deer damage to agricultural crops continues to be a critical and challenging issue for wildlife managers. With a growing number of farmers leasing land for hunting, balanced management strategies that reduce crop damage to acceptable levels and produce quality deer populations are important. To achieve these results, it may be necessary for managers to go beyond traditional broad guidelines and integrate specific deer harvest and habitat management practices on a localized scale.

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