ABSTRACT

KARNS, GABRIEL RYAN. Impact of Hunting on Adult Male White-tailed Deer Behavior.
(Under the direction of Richard A. Lancia and Christopher S. DePerno.)

The impact of hunting pressure on white-tailed deer behavior has been broadly studied, but specific examination of the interaction between adult male deer and hunters has not been conducted using global positioning system (GPS) technology. During 2006-2007, my research focused on the interaction between adult male white-tailed deer and hunters at Chesapeake Farms, a privately owned property in Kent County, Maryland. I affixed GPS collars affixed to 19 adult male white-tailed deer and investigated changes in home range and core area size, shifts in home range and core area, movement, activity, vulnerability, and refuge use using an analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test. Movement decreased during dawn ($F = 6.284$, $df = 24$, $P = 0.006$) and day ($F = 11.060$, $df = 24$, $P < 0.001$) hours, and activity decreased during day ($F = 6.289$, $df = 24$, $P = 0.006$) hours. No significant differences in home range, core area, vulnerability, and refuge use parameters were observed indicating that changes in movement and activity were unlikely a sole function of Maryland's 2-week hunting season. Rather, decreases in movement and activity were more likely a by-product of temporal correlation between hunting season and the post-breed season (when such decreases in activity would be expected). I concluded that hunters on Chesapeake Farms did not exert sufficient hunting pressure to induce noticeable behavioral change in adult male white-tailed deer. Combining data gathered from the GPS-collared adult males with a previous study (Tomberlin 2007), I analyzed adult male excursions outside of their home range during the fall and winter months. A total of 30 excursions were documented and the majority of adult males (53%) engaged in at least one excursion during study periods. Twenty-two excursions

(73%) were made during the pre-breed 2 or breeding periods, and breeding-season related motives seemed to be the driving force behind most adult male excursions. By comparing excursions during hunting season with known hunter locations, it is unlikely that hunting was an instigating factor for excursions at Chesapeake Farms.

In addition to the GPS collar research, a catch-per-unit-effort (CPUE) estimator was improved by converting FORTRAN (IBM, Armonk, New York) code (Bishir et al. 1996) to JMP scripting language (JSL) (SAS Institute, Cary, North Carolina). The method was validated by comparing previous (1981-1991) FORTRAN estimates of the antlered male population at Chesapeake Farms, MD, to JMP estimates. Also, I tested the CPUE-JMP estimator's effectiveness with regards to varying length hunting seasons and traditional versus quality deer management (QDM) paradigms. The new method improved estimates by 25%, and different season lengths and deer management regimes did not have a significant impact on estimates. Long-term trends produced by the CPUE-JMP estimator were sufficient for most harvested big-game population management applications.

Lastly, I examined the natural mortality factor of intracranial abscessation in the adult male white-tailed deer population at Chesapeake Farms, MD. From 2003-2007, mortality was documented for and necropsies performed on 26 GPS-collared adult males. Adult male mortality due to intracranial abscessation was disproportionately high (35%) compared to the national average (9%), and if additive to other natural mortality factors and hunter harvests could pose a serious obstacle to achievement of QDM objectives.

Impact of Hunting Pressure on Adult Male White-tailed Deer Behavior

by
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DEDICATION

I dedicate my thesis to my Grandma. You are the most generous and caring person I know. My incurable deer obsession started right there at you and Grandpa's farm. Thank you for everything and I love you.

BIOGRAPHY

Gabriel Ryan Karns was born in Oil City, Pennsylvania, on June 6, 1984. Before moving to Burlington, North Carolina, he spent his elementary years in Columbia, South Carolina. After graduating from Alamance Christian School in May 2003, he entered the wildlife sciences program at North Carolina State University. Continuing at North Carolina State University, he began his graduate degree in January 2007. On January 5, 2008, Gabriel was married to Kara Dawn Stewart of Elon, North Carolina, before completing his graduate schooling in December 2008. In January 2009, he is stepping into a doctorate position at Auburn University, Alabama. His long-term plans are to conduct wildlife research and teach wildlife science curriculum at a university.

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INTRODUCTION

The scientific literature is replete with research conducted on white-tailed deer (*Odocoileus virginianus*) fawns, juvenile males, juvenile females, and adult females. At Chesapeake Farms, Maryland, numerous studies have been conducted on white-tailed deer including natal dispersal and survival of juvenile males (Rosenberry et al. 2001), genetic mating systems of white-tailed deer (Shaw 2005), and observability of females using radio telemetry (Wallingford 1990). Less is known about adult male deer because they generally constitute the smallest portion of many harvested white-tailed deer populations (Campbell et al. 2005). At Chesapeake Farms, the study of adult male deer was feasible because under quality deer management (QDM) an older age class structure has developed through the protection of yearling male deer from harvest. Tomberlin (2007) examined habitat use, movement, and activity of adult males during the late summer, fall, and early winter; however, the study did not focus on the interaction between hunters and white-tailed deer, and hunting season data were lumped into more general post-breed and winter periods.

At Chesapeake Farms and other properties that generate portions of their annual income from deer hunting, understanding the dynamics of the interaction between hunting and adult male white-tailed deer is important. Much of the published research examining the impact of hunting pressure on white-tailed deer behavior has used very high frequency (VHF) radiocollars and focused primarily on adult females and juvenile males (Chapter 1). These studies have been conducted primarily in traditionally managed populations and the level of hunting pressure exerted and amount of available escape and security cover seem to predict the degree of behavioral response by white-tailed deer to hunting disturbance (Autry 1967, Sparrowe and Springer 1970, Pilcher and Wampler 1981, Root et al. 1988, Kilpatrick et al. 1999). In habitats that provide deer with adequate cover, deer usually stay within their home ranges and decrease diurnal activity levels but increase movements to avoid hunters when necessary (Pilcher and Wampler 1981, Root et al. 1988, Kilpatrick et al. 1999). In regions lacking quality security cover, white-tailed deer were more likely to be active during the day, temporarily leaving their home ranges to escape hunters (Sparrowe and Springer 1970). On many QDM-managed properties, abundant resources are invested to increase the numbers and quality of older age class males for hunters, but the dividends of trophy deer are not always realized with fewer older age class males harvested than expected. Because little research has been conducted on the effects of hunting on adult male white-tailed deer, managers are unable to predict how hunting influences the behavior of adult male white-tailed deer so they can develop strategies to minimize that impact, while maximizing hunter opportunity and success.

With global positioning system (GPS) technology, I studied the behavioral response of adult male white-tailed deer to hunting during Maryland's 2-week shotgun season. Although past research has examined adult male response to hunting pressure in regions of Florida, South Texas, and publicly-accessed refuges in Oklahoma and Illinois (Autry 1967, Pilcher and Wampler 1981, DeYoung 1989, Sargent 1992), no research has been conducted in an agricultural landscape (such as the Delmarva Peninsula), and none has used GPS collars. By analyzing home range and core area size and distribution, movement, activity, utilization of refuges, and avoidance of human activity areas, the effects of hunting pressure on adult male white-tailed deer behavior at an intensively-managed QDM property can be determined and, if necessary, changes to hunting regimes at Chesapeake Farms can be implemented to achieve harvest and management goals.

Through prior research at Chesapeake Farms, Tomberlin (2007) noted that 58% of adult males made excursions during the breeding season, with a smaller number of extraneous movements occurring before and after the breeding season. Because frequent excursions can predispose adult males to increased harvest vulnerability on neighboring properties (Nixon et al. 1991, Tomberlin 2007) and can function in landscape level processes such as gene flow and disease transmission (Rosenberry et al. 1999, McCoy et al. 2005, Schauber et al. 2007), I examined the temporal and spatial distribution of excursions and hypothesized what motives drive adult male white-tailed deer to make extraneous movements outside their home ranges. Hawkins and Klimstra (1974) suggested that adult males venture outside their home range to search for receptive females, or a male white-tailed deer might be following an estrous female back to her core area (Holzenbein and Schwede 1989). Also, excursions might be exploratory movements to locate food sources or instigated by disturbances such as hunting or ranching activities (Hood and Inglis 1974, Naugle et al. 1997, Vercauteren and Hygnstrom 1998). By plotting movements to a timeline structured around possible motives for excursions and cross-examining adult male excursions with GPS data collected from adult females during the breeding season (J. Kolodzinski, unpublished M.S. data, University of Georgia), hypotheses can be tested concerning why adult males make movements outside their normal home range before, during, and after the breeding season. If evidence indicates excursions are driven by a limiting resource (shifting winter food source) or instigated by excessively disturbing hunting practices, management efforts on Chesapeake Farms can mitigate these factors and increase the survival rate of adult male white-tailed deer by decreasing the necessity of excursions.

Understanding the behavioral response of white-tailed deer to hunting and the dynamics of excursions throughout the fall and winter months is important, but accurate and precise estimates of population size are fundamental to outlining sound management objectives for harvested populations (Caughley 1977). Having precise and accurate estimations of overall population size and segments of animals within the herd enables managers to understand population dynamics, determine success or failure of previous actions, and prescribe specific goals and objectives for future management objectives (Conner 1988, Novak et al. 1991, Rosenberry et al. 1999, Shaw et al. 2006). Bishir and Lancia (1996) developed a catch-per-unit-effort population estimator that performed well in situations where hunters diligently recorded accurate catch and effort data, but unfortunately the FORTRAN coding was cumbersome, data input was difficult, and computation speed was slow. By improving the user-friendliness of the technique and validating the new method on previous estimates of the antlered male population at Chesapeake Farms, managers can be equipped with an excellent tool to accurately estimate the white-tailed deer herd and better prescribe specific management goals by examining long-term population trends and determining the success and failure of previous management strategies.

Often, natural mortality factors are overlooked by managers of harvested game populations. In situations where natural hazard rates are indeed low, this oversight might be acceptable; however, this is rarely the case. Generally, natural mortality factors account for small proportions of juvenile and older age class deaths (Campbell et al. 2005); but at Chesapeake Farms, evidence suggests that intracranial abscessation accounts for a large proportion of adult male mortality. Caused by the bacteria *Arcanobacterium pyogenes*, intracranial abscessation is commonly overlooked by natural resource agencies because it accounts for less than 5% of natural mortality in studied regions (Davidson et al. 1990, Baumann et al. 2001). However, it is believed that intracranial abscessation accounts for a large proportion of adult male mortality at Chesapeake Farms compared to other areas of the country and that QDM efforts to maintain large numbers of older age class male white-tailed deer could be hindered. Understanding the true impact of intracranial abscessation on adult male populations at Chesapeake Farms will allow managers to account for this natural mortality factor in making management decisions involving the adult male segment of the white-tailed deer herd.

Study Area

Chesapeake Farms was located on the Eastern Shore of the Chesapeake Bay in Kent County, Maryland, 10 km southwest of Chestertown (N 39°10', W 76°10'), with a mean elevation of 13 meters above sea level (McLeod and Gates 1998). Owned and operated by DuPont Agricultural Enterprise, Chesapeake Farms was a 1,300-ha wildlife management and agricultural research demonstration area. Approximately 50% of the study area was forested with non-alluvial swamps that consisted primarily of oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), and red maple (*Acer rubrum*). Greenbriar (*Smilax* spp.), sweet pepperbush (*Clethra alnifolia*), and highbush blueberry (*Vaccinium corymbosum*) dominated the understory. Cash crops [field corn (*Zea mays*), soybeans (*Glycine max*), and winter wheat (*Triticum* spp.)] composed 20% of the study area. Fallow fields composed 13% of the farm [orchard grass (*Dactylis glomerata*), clover (*Trifolium* spp.), sorghum (*Sorghum* spp.), and rye (*Lolium multiflorum*)]. The remaining 17% was composed of non-forested wildlife cover and man-made waterfowl impoundments (Shaw 2005).

Chesapeake Farms' deer density was most recently estimated to be 33 deer/km^2 (Shaw 2005). In addition to minimal harvest during the archery and muzzleloader seasons (~10/year), the majority of deer harvest at Chesapeake Farms occurred during Maryland's 2-week shotgun season from the first Saturday after Thanksgiving for 2 continuous weeks. From pre-1993, the shotgun season was 1 week long. To reduce over-abundant population levels, annual harvests approached and sometimes exceeded 200 deer during the mid- to late-1990s (Rosenberry et al. 1999). Simultaneously, in 1994, Chesapeake Farms underwent a change from a traditional harvest (any antlered male is legal) to a selective male harvest (Shaw 2005). To be legally shot, a male was required to have at least 7 points. In 1997, the selective male harvest criterion was adjusted: only males with ear-tip-wide outside antler widths (approximately 40-cm) could be harvested (Shaw 2005).

Because of harvest restrictions, the male age class structure on Chesapeake Farms shifted, and harvest moved from younger males (mostly 1.5-year-old males) to being predominantly 2.5- and 3.5-year-old males and older (Shaw 2005). During 1989-1993, eighteen 1.5-year-old males were harvested and seven 3.5-year-old and older males were harvested on average (Shaw 2005). From 1999-2003, only three 1.5-year-old males and seventeen 3.5-year-old and older males were harvested on average (Shaw 2005). From 2000-2002, an average of 153 females were harvested (Shaw 2005), but female harvests decreased in the past 5 years (~100). Because more harvest pressure was placed on females in recent years, the sex ratio became increasingly balanced (Rosenberry et al. 2001); the most recent male:female ratio estimate was 1:1.5 (M.C. Conner, Manager, Chesapeake Farms, unpublished data).

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IMPACT OF HUNTING PRESSURE ON ADULT MALE WHITE-TAILED DEER BEHAVIOR

Abstract

Hunting pressure can lead to drastic changes in white-tailed deer (*Odocoileus virginianus*) behavior; however, this phenomenon has not been extensively studied in adult males using GPS technology. During 2006-2007, I deployed GPS collars on 19 adult ($\geq$ 2.5-years-old) male white-tailed deer to examine changes in home range and core area size, shifts in home range and core area, movement, activity, vulnerability, and refuge use during Maryland's 2-week firearms season. Adult male white-tailed deer reduced movement and activity levels during the hunting season, but most aspects remained stable before, during, and after hunting season. Hunting pressure on Chesapeake Farms was not sufficient to induce a significant change in behavior of adult male white-tailed deer, but more intense hunting pressure on surrounding properties caused deer to use Chesapeake Farms as a refuge during the 2-week firearms season.

Introduction

Previous studies on the effects of hunting on the behavior of white-tailed deer (*Odocoileus virginianus*) have used Global Positioning System (GPS) and/or very high frequency (VHF) radiocollars and observations of marked animals to study fidelity and size of home-ranges and core areas, activity levels, movement, flight to un-hunted refuges, changes in habitat use, and vigilance behavior (Autry 1967, Marshall and Whittington 1968, Kammermeyer and Marchinton 1976, Grau and Grau 1980, Pilcher and Wampler 1981, Root et al. 1988, Sargent 1992, Kilgo et al. 1998, Vercauteren and Hygnstrom 1998, Kilpatrick and Lima 1999, Lark and Slade 2008). With the advent of GPS collar technology, researchers are equipped with the ability to acquire fine-scale sequential locations for each individual study animal (Frair et al. 2004, Graves and Waller 2006). Combining GPS collars with Geographic Information Systems (GIS), micro-temporal and micro-spatial aspects of behavioral response to hunting pressure can be studied (Broseth and Pedersen 2000). Additionally, hunter effort and pressure can be continuously logged using additional GPS units or rigorous data recording at known stand locations (Broseth and Pedersen 2000). Unfortunately, GPS collars are more expensive than traditional telemetry equipment, and the advantage of increased data quality with GPS technology can be hampered by the cost of fewer animals being sampled which results in studies with lower statistical power (Otis and White 1999).

Because of over-selective hunting pressure and high juvenile male mortality, adult male white-tailed deer are typically the smallest and the least studied segment of free-ranging populations (Campbell et al. 2005). Although adult bucks have been studied with VHF radiocollars (Van Etten et al. 1965, Autry 1967, Kammermeyer and Marchinton 1976, Root et al. 1988, Sargent 1992), to my knowledge, no prior GPS research has been conducted solely on the interaction of hunting pressure and adult male white-tailed deer behavior. Hunting pressure varies throughout regions [10-77 hunters/km^2, Pennsylvania (Murphy 1962); 35 hunters/km^2, Maryland (Kennedy 1974); 60 hunters/km^2, Michigan (Cue and Langenau 1979); 4-19 hunters/km^2, Pennsylvania (Diefenbach et al. 2005)] and makes comparison between studies difficult. Many studies do not report measures of hunting pressure or they vary so widely across the study area that reported levels are of little use, contributing to the wide range of behavioral response by white-tailed deer to hunting pressure. Also, because hunting and breeding seasons coincide in many regions, it is difficult to differentiate male white-tailed deer responses to hunting pressure versus breeding season-related behavioral fluctuations (Tomberlin 2007). This potential interaction could be further obscured because deer populations apparently do not alter their behavior in response to hunting pressure below certain thresholds (Root et al. 1988, Autry 1967).

Home range was defined by Burt (1943) as "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young." Deer home range size and utilization of the landscape is a function of age, sex, habitat quality, population density, season, available food sources, and cover (Montgomery 1963, Ellisor 1969, Larson et al. 1978, VerCauteren and Hygnstrom 1998, Demarais et al. 2000, Powell 2000, Kilpatrick et al. 2001). During breeding season, adult males occasionally venture outside their normal home range and range size expands (Hawkins and Klimstra 1970, Guyse 1978, Hosey 1980, Tomberlin 2007). Female home ranges decrease from the pre-rut to the post-rut (Holzenbein and Schwede 1989, Ivey and Causey 1981). Such inherent behavioral differences between males and females necessitate that research examining the influence of hunting pressure on behavior study sexes independently.

White-tailed deer exhibit high fidelity to established home ranges during periods of high disturbance (e.g., hunting season and intensive ranching; Autry 1967, Marshall and Whittington 1968, Hood and Inglis 1974, Kammermeyer and Marchinton 1976, Pilcher and Wampler 1981, Kufeld et al. 1988, Root et al. 1988, Nixon et al. 1991, Naugle et al. 1997, Kilpatrick and Lima 1999). However, individual deer might respond to hunting pressure differently by shifting their home range away from areas of high human activity towards more secure cover or by completely isolating themselves to non-hunting refuges for the duration of the hunting season (Kammermeyer and Marchinton 1976, Kufeld et al. 1988, Root et al. 1988, Kilgo et al. 1998, Vercauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). In nearly all cases where deer shift home ranges to non-hunting refuges during hunting seasons, they return to their normal home range shortly after hunting season ends (Pilcher and Wampler 1981, Vercauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). In areas where escape cover is sparse and deer must travel longer distances to avoid hunter disturbance, white-tailed deer home ranges increase during hunting season (Sparrowe and Springer 1970). Also, in regions of the United States where security cover is not a limiting factor, home range size increases during archery and firearms hunting seasons (Pilcher and Wampler 1981, Root et al. 1988, Kilpatrick et al. 1999). Although, in some other studies, home range size remains stable before, during, and after hunting seasons (Downing et al. 1969, Vercauteren and Hygnstrom 1998).

Core area distribution and intensity of use are closely related to home range dynamics (Guiness and Albon 1982), but are less understood in white-tailed deer studies. Core areas (i.e., centers of activity; Dixon and Chapman 1980) are used more frequently than the rest of an animal’s home range and usually contain major food sources, bedding areas, or refuges (Burt 1943, Kaufmann 1962, Ewer 1968, Byford 1969). Seaman et al. (1999) suggested that core areas should be the primary focus of utilization distribution studies because outer home range contours are often unreliably estimated. Intensity is a proportional measure of how concentrated core areas are within the home range (Lent and Fike 2003).

Ungulate behavior typically revolves around a feeding/resting/feeding rhythm, and core areas typically reflect bedding areas in cover and feeding areas in open habitat (Gill 1966, Huot 1974, Armstrong et al. 1983). During the breeding season in high density populations, females concentrate activity inside core areas and males decrease core area use as they search for receptive females (Downing et al. 1969, Ivey and Causey 1981, Holzenbein and Schwede 1989, Beier and McCullough 1990). In low density populations, female core area use decreases from pre-rut to rut because females have to increase movements throughout their home range and adopt a different breeding season strategy to find a suitable mate (Labisky and Fritzen 1998). In hunting season, Root et al. (1988) noted that centers of activity (core areas) did not vary geographically or in size, indicating that deer utilize their most familiar territory when threatened and disturbed. In contrast, Kilpatrick and Lima (1999) stated that core areas shift to more secure cover (Vercauteren and Hygnstrom 1998) and increase in size for hunted deer, whereas unhunted deer core area distribution and size remain the same.

In addition to home range and core area dynamics, deer movement and activity can be influenced by hunting pressure. Throughout much of the year, deer movement primarily occurs as animals move from bedding areas to feeding areas and vice versa. However, in the rut, movement increases as males seek receptive mates and establish dominance hierarchies (Downing et al. 1969, Moore and Marchinton 1974, Nelson and Mech 1981), whereas female movement might increase (Labisky and Fritzen 1998) or decrease (Holzenbein and Schwede 1989) depending on which breeding strategies are adopted in relationship to density and sex ratio of a population.

The effect of hunting pressure on deer movement depends largely on the amount and quality of cover in a landscape (Marshall and Whittington 1968, Sparrowe and Springer 1970, Pilcher and Wampler 1981, Lagory 1987, Root et al. 1988). In several studies examining the influence of hunting pressure on white-tailed deer behavior, deer decreased diurnal movement during hunting season and remained stationary in dense security cover (Autry 1967, Nixon et al. 1991, Kilpatrick and Lima 1999). During a 1-week muzzleloader hunting season, deer did not move (any distance perceptible to radio telemetry) outside their core bedding area until the season ended (Vercauteren and Hygnstrom 1998). In contrast, deer might increase diurnal movement by frequent flight responses to hunting-related disturbances, yet remain within their normal home range (Van Etten et al. 1965, Marshall and Whittington 1968, Dorrance et al. 1975, Root et al. 1988, Naugle et al. 1997). Pilcher and Wampler (1981) noted that daytime movement increased 2-fold for females and 3-fold for males during hunting season; and Root et al. (1988) concluded that mobility of non-refuge females peaked during hunting season and was greater than refuge female movement, but male movement remained stable. If disturbances are severe enough, deer might exhibit temporary flight movements outside of their home range to avoid hunters (Downing et al. 1969, Pilcher and Wampler 1981, Sparrowe and Springer 1970, Kammermeyer and Marchinton 1976), though these movements can easily be confused with unusual breeding season movements (Guyse 1978, Hosey 1980, Holzenbein and Schwede 1989, Labisky and Fritzen 1998).

White-tailed deer exhibit circadian activity rhythms with major peaks occurring at dawn and dusk with minor nocturnal peaks (Montgomery 1963, Ozoga and Verme 1970, Ozoga and Gysel 1972, Zagata and Haugen 1974, Kammermeyer and Marchinton 1976, Ivey and Causey 1981, Beier and McCullough 1990, Coulombe et al. 2006, Tomberlin 2007). During the breeding season, overall activity might increase (Ozoga and Verme 1975, Ivey and Causey 1981) or decrease (Holzenbein and Schwede 1989). Naugle (1997) stated that deer might respond to hunting pressure by altering activity levels, and deer are likely to decrease diurnal activity levels and seek cover during the hunting season (Autry 1967, Nixon et al. 1991).

Vulnerability, where hunting takes place from permanent hunting stands, is a direct function of the amount of diurnal movement, activity, and distances traveled by deer within hunting areas (Roseberry and Klimstra 1974). Many additional factors, including deer density, habitat type and fragmentation, weather, hunter density, hunting season length, topography, and agricultural crop availability influence white-tailed deer vulnerability (Fobes 1945, Van Etten et al. 1965, Holsworth 1973, Hanson et al. 1986, Vercauteren and Hygnstrom 1998). Deer are most vulnerable in open habitats, but less vulnerable to hunter harvest in landscapes characterized by large contiguous forests (Swenson 1982). Also, differences in white-tailed deer behavior place certain segments of the population at higher risk than others. Inherently, males exhibit greater mobility than females and consequently are more vulnerable to hunter harvest (Murphy 1962). Dispersing yearling males are the most vulnerable cohort because they commonly traverse long distances through unfamiliar territory (McCoy et al. 2005, Rosenberry 1997, Rosenberry et al. 1999, Rosenberry et al. 2001), and 1.5-2.5-year-old males are more vulnerable than older age class males early in hunting seasons (Maguire and Severinghaus 1954, Roseberry and Klimstra 1974). Breeding-season related and hunting-induced excursions by males and females increase vulnerability and risk of vehicle collision (Nixon et al. 1991, Tomberlin 2007). Further, any increased movement during legal hunting hours in hunted areas should be matched by a proportional increase in vulnerability.

Occasionally, a perceived decrease in vulnerability to harvest is actually a decline in availability as deer move out of hunted areas and into refuges where hunting is either prohibited or hunter access is difficult and limited (e.g., swamps and large contiguous forests) (Roseberry and Klimstra 1974, Larson et al. 1978, Naugle et al. 1997, Kilgo et al. 1998, Kilpatrick and Lima 1999). Although some white-tailed deer hide in dense security cover (Kufeld et al. 1988, Vercauteren and Hygnstrom 1998, Kilgo et al. 1998) or increase movement to avoid hunting pressure (Autry 1967, Root et al. 1988), others might utilize refuges inside their home ranges. In areas where white-tailed deer traditionally utilize no-hunting zones during hunting season, deer quickly shift their home range to refuges when hunting pressure starts, but return to their pre-hunt home ranges shortly thereafter (Zagata and Haugen 1973, Kammermeyer and Marchinton 1976, Rodgers et al. 1978, Vercauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). In many states, hunters exert far more pressure on antlered males than females, and Root et al. (1988) noted that males shifted home ranges to center on refuges, whereas females did not.

Even without refuges, white-tailed deer can drastically reduce their risk of harvest by shifting their diurnal activities further into large, contiguous blocks of wooded habitat and increasing their distance from roads and hunting stand locations. Broseth and Pedersen (2000) noted that hunting pressure in a given area is principally predicted by the presence of and proximity to roads, and Kilgo et al. (1998) stated the majority of hunting takes place within 200 meters of roads. Consequently, when disturbances reach an intolerable threshold, deer (Rost and Bailey 1979, Dorrance et al. 1975, Kilgo et al. 1998) and other ungulates (Schultz and Bailey 1978, Conner et al. 2001, Johnson et al. 2004) avoid habitats near roads. Among other measures, one can use home range and core area polygon centroids or mean center of fixes to examine this possible interaction.

Objective:

Evaluate the influence of hunting pressure on adult male white-tailed deer behavior.

Methods

From June-August, 2006-2007, I captured 19 [2006 (n=10) and 2007 (n=9)] adult male white-tailed deer; adult deer are defined as ≥ 2.5-years-old. I estimated deer age in the field by using antler and body characteristics (Richards and Brothers 2003) and used a Dan-Inject JM Standard dart projector (Dan-Inject, Inc., Fort Collins, Colorado, USA) and 3-ml radio transmitter darts (Pneu-dart, Inc., Williamsport, Pennsylvania, USA) to administer anesthetic drug combinations of 2.4 ml Telazol (200 mg/ml; Fort Dodge Animal Health, Fort Dodge, Iowa, USA) and 0.6 ml Xylazine (450 mg/ml; Wildlife Laboratories, Inc., Fort Collins, Colorado, USA) (Kreeger et al. 2002) or 0.5 ml Medetomidine (20 mg/ml; Wildlife Laboratories, Inc., Fort Collins, Colorado, USA), 1.0 ml Ketamine (200 mg/ml; Fort Dodge Animal Health, Fort Dodge, Iowa, USA), and 1.4 ml Telazol (200 mg/ml) (Muller et al. 2007). The transmitter dart allowed us to track the deer using radio telemetry equipment (Telonics, Inc., Mesa, Arizona, USA). If the animal was not fully sedated when located, I administered an additional 1.1 ml Ketamine (200 mg/ml) booster intramuscularly by syringe.

Once fully immobilized, I applied eye ointment (Paralube, Pharmaderm, Melville, New York, USA) to prevent corneal drying and blindfolded the animal to minimize stress. The deer were positioned sternally or on right side for processing. I monitored vital signs (open airway, pulse, respiration, temperature) on initial approach and every 15 minutes throughout the procedure. I surgically removed darts, flushed the puncture with Betadine (Purdue Pharma, L.P., Stamford, Connecticut, USA), and applied antibiotic cream (Farnam Companies, Inc., Phoenix, Arizona, USA) to the wound. A broad spectrum antibiotic (i.e., LA 200; 1 ml/11.34 kg; Pfizer Animal Health, Exton, Pennsylvania, USA) was administered intramuscularly to 2 sites in the hindquarter. I fitted each deer with a Lotek 3300L GPS collar (Lotek Engineering, Ontario, Canada) and tightened them within 8 cm (approximately 4 fingers width) of the deer's neck to accommodate for neck swelling associated with breeding season. Although each collar was equipped with a 32-week time-delay release mechanism, a remote-release mechanism allowed us to disengage the collar in case of emergency. To assist in field identification, each deer received colored and numbered cattle ear tags (National Band and Tag, Co., Newport, Kentucky, USA). Also, I placed uniquely numbered Monel tags (National Band and Tag, Co., Newport, Kentucky, USA) in both ears. For future genetic analysis, I cut a small ear notch from each deer and froze the sample.

At 70 minutes post-injection, I reversed Xylazine/Telazol-anesthetized deer with 3.3 ml Tolazoline (100 mg/ml; Lloyd Laboratories, Shenandoah, Iowa, USA), one-half intramuscularly and one-half intravenously. I used 10.0 ml atipamezole (5 mg/ml; Pfizer Animal Health, Exton, Pennsylvania, USA) to intramuscularly reverse deer anesthetized with Medetomidine/Ketamine/Telazol. Seventy minutes was adequate time for the Telazol and/or Ketamine to dissipate from the deer's system and eliminate the risk of anesthetic relapse (Tomberlin 2007). I monitored deer until they were capable of independently leaving the processing site. The research protocol was reviewed and approved by the Institutional Animal Care and Use Committee at North Carolina State University (#05-024-0).

GPS Collars

I programmed 3300L Lotek GPS collars to collect hourly fixes throughout deployment. Because micro-scale data was desired during breeding and hunting seasons, I programmed the collars to acquire fixes every 20 minutes from 5 November – 12 December in 2006. From 15 October – 15 December, 2007, I programmed the collars to acquire fixes on a 5-minute schedule for even finer scale data. GPS collars recorded geographic coordinates, date, time, environmental temperature, fix status, and a position dilution of precision (PDOP) value with each fix. Collars were equipped with a mortality sensor that triggered after 8 hours inactivity and emitted a double-pulse VHF signal. To ensure collars were properly functioning and study animals were alive, deer were monitored twice weekly using radio telemetry equipment. If mortality sensor was activated (deceased study animal or released collar), the collar was retrieved using radio telemetry. Also, collars were equipped with a dual-axis activity sensor. Within every 5-minute interval, collars separately recorded the number of times (0 to 255) the horizontal and vertical orientation of the head or neck of the deer changed – 0 indicating no activity and 255 indicating maximum activity (Coulombe et al. 2006). To retrieve fix and activity data, recovered collars were linked to Lotek's download unit, and data were transferred to a computer.

Data Censoring

To delete possible erroneous fixes from the dataset, I ran all fixes through a pre-determined set of quality control screenings and omitted all 3-dimensional (3D) fixes with PDOP > 10 and 2-dimensional (2D) fixes with PDOP > 5 from analyses (Adams 2003, D'Eon and Delparte 2005, Tomberlin 2007). In addition to the PDOP filter, I omitted all fixes with altitudes outside the range of -100 meters to 100 meters (D'Eon and Delparte 2005, Tomberlin 2007). Also, I removed malfunctioned fixes as indicated by VHF pulse rates or absent VHF signal (Tomberlin 2007). To reduce the possible bias of post-capture stress, I deleted the 7 days following capture from all data analyses (Tomberlin 2007).

Finally, if the deer died before data collection was complete, I deleted 7 days pre-mortem to avoid possible bias.

Study Periods

For possible data pooling and comparison to a previous study (Tomberlin 2007), I defined the pre-breed period as 15 October – 4 November. Based on parturition and fawn capture data collected during a previous study and a 200-day gestation period for white-tailed deer, pre-hunt period (which coincides with breeding season) was defined as 5 November – 24 November (2006) and 5 November – 23 November (2007) (Plotka et al. 1982, Tomberlin 2007). In 2006, the hunt period was 25 November – 9 December and 24 November – 8 December in 2007. Hunt periods coincided with Maryland's annual 2-week shotgun season. I defined the post-hunt period as 10 December – 6 January (2006) and 9 December – 6 January (2007). For comparing different periods of the day, I defined dawn (3 hours) as the hour in which sunrise occurred and the hour before and after; dusk (3 hours) as the hour in which sunset occurred and the hour before and after; day as the period between dawn and dusk; and night as the period between dusk and dawn.

Data Analysis

After data censoring, I imported GPS fixes for each deer into ArcMap 9.2 (Environmental Systems Research Institute, Inc., Redlands, California, USA) for data analyses. I projected all data in Universal Transverse Mercator (UTM) North American Datum (NAD) 1983 Zone 18 North (meters).

I used top-hour fixes from 7 days post-capture to the end of the post-hunt period to generate overall home ranges and core areas using 'Kernel Density Estimator' and 'Percent Volume Contour' in Hawth's Analysis Tools (Beyer 2004). I calculated home ranges and core areas using 95% and 50% fixed kernel methods, respectively. A smoothing parameter [200] was chosen based on a close examination of a wide range of possible values and comparing corresponding polygons to true distribution of GPS fixes (Laver 2005). Also, I calculated home ranges and core areas for the pre-hunt, hunt, and post-hunt periods for each deer. I calculated intensity of use for overall, pre-hunt, hunt, and post-hunt periods by using core area: home range ratio (Lent and Fike 2003). I compared home range, core area, and intensity values between study periods.

Using successive top-hour fixes, I calculated straight-line distances between fixes. Where gaps existed in the dataset because of missed or deleted GPS fixes, the movement on one hour of either side of that GPS fix was omitted from analysis. Using “Convert Locations to Paths” in Hawth’s Analysis Tools (Beyer 2004), I calculated and compared movement during dawn, day, dusk, and night for the pre-hunt, hunt, and post-hunt periods. Also, I examined micro-scale movements (5, 20-minute fix interval) by adult male deer in relation to known hunter locations during 2006 and 2007 firearms season. All hunting stands, time dropped off, and time picked up, were recorded by hunting guides at Chesapeake Farms.

Because the horizontal (x-axis) activity sensor is overly sensitive and tends to misclassify bedded animals as active, I chose to use data from the vertical (y-axis) sensor only (Beier and McCullough 1988, Coulombe et al. 2006). For inclusion in analysis, I used the vertical activity value collected during the 5 minutes prior to each top-hour fix. I compared activity for dawn, day, dusk, and night between the pre-hunt, hunt, and post-hunt periods.

To estimate the vulnerability of deer to harvest during shotgun season, I buffered each permanent hunting stand to 100 meters (approximate maximum effective range of slug shotguns) and intersected all top-hour fixes during the pre-hunt, hunt, and post-hunt period with the 100-meter hunting stand buffer to calculate vulnerability. I did not require hunting stands to be occupied by a hunter for this analysis, although all stands were used periodically throughout the firearms season. Any deer with a fix inside the hunting stand buffers during the dawn, day, or dusk was considered vulnerable to harvest for that single GPS fix. I defined the vulnerability value as the ratio of vulnerable locations to total locations during dawn, day, and dusk, and compared dawn, day, and dusk vulnerability values between pre-hunt, hunt, and post-hunt periods.

Although the study site did not have designated refuges, large areas existed where firearm hunting did not occur. These areas were void of hunting stands and were only entered to retrieve deer. I defined and digitized refuges as areas $\geq$ 30.35 hectares, in which there were no hunting stands, and with boundaries established 100 meters from hunting stands, roads, leased or neighboring property boundaries (Fig. 1). For analysis, refuge use was calculated using the ratio of fixes inside refuges to total fixes. I compared dawn, day, dusk, and night refuge use between pre-hunt, hunt, and post-hunt periods.

I used "Generate Polygon Centroid Points" in Hawth's Analysis to calculate the polygon (geometric) centroids of 95% (home range) and 50% (core area) volume contours for each deer (Beyer 2004). After I generated polygon centroids for pre-hunt, hunt, and post-hunt periods for each deer and measured the distance from each polygon centroid to the nearest road and nearest hunting stand located on Chesapeake Farms, I compared distance from centroids to nearest road and nearest hunting stand between pre-hunt, hunt, and post-hunt periods.

I used "Mean Center" in ArcToolbox (Environmental Systems Research Institute, Inc., Redlands, California, USA) to calculate the arithmetic mean center of fixes for pre-hunt, hunt, and post-hunt periods for each deer. After mean centers were generated for each period, I measured and compared the distance from each mean center to the nearest road and nearest hunting stand located on Chesapeake Farms between pre-hunt, hunt, and post-hunt periods.

Using "Distance between Points" in Hawth's Analysis Tools (Beyer 2004), I calculated the distance between each top-hour fix and the nearest hunting stand located on Chesapeake Farms during the pre-hunt, hunt, and post-hunt periods. I compared fix distance to nearest hunting stand for dawn, day, dusk, and night between the pre-hunt, hunt, and post-hunt periods.

Statistical Analysis

All comparisons were evaluated using an analysis of variance model (ANOVA) followed by Tukey's honestly significant difference (HSD) test. Alpha was set at 0.05; all statistical analyses were performed in SYSTAT Version 10 (Wilkinson 1990).

Results

GPS Collar Performance

A total of 19 collars (10 in 2006, 9 in 2007) were deployed in the study. All collars were eventually retrieved, but only 4 and 5 collars collected useable data during 2006 and 2007, respectively. In 2006, 3 collared deer died of intracranial abscessation during October and November (Karns et al. in press), 2 collars had mechanical failure and prematurely released from the study animals before the hunting season, and one collar sustained drop-off mechanism and GPS wiring damage and was retrieved in March 2008. In 2007, 2 collared deer died of epizootic hemorrhagic disease (EHD), 1 study animal was harvested by an archery hunter on an adjoining property, and 1 deer suffered capture-related mortality. The aforementioned 10 collars were censored from the study.

During the study periods in 2006, Lotek 3300L GPS collars collected 50,002 total fixes based on the 20-minute, 1-hour fix interval schedule. I cleansed 6,567 fixes from the 2006 dataset based on PDOP and altitude thresholds and malfunctioned fixes. In 2007, with the 5-minute, 1-hour fix interval schedule, collars collected 115,852 total fixes and 10,519 were omitted because of failure to meet data quality specifications. A total of 86.9% (43,436) of the total 2006 GPS collar fixes and 90.9% (105,333) of the 2007 fixes met data requirements. I pooled 2006 and 2007 deer for data analyses.

Home range and core area

Mean overall home range (95%) size was 386 (SE = 129) ha and core area (50%) size was 81 (SE = 27) ha. Between the pre-hunt, hunt, and post-hunt periods, I detected no difference in mean home range (95%) size (F = 0.466, df = 24, P = 0.633) (Table 1) or mean core area (50%) size (F = 0.940, df = 24, P = 0.404) (Table 1). Overall intensity value was 0.22 (SE = 0.07), and I detected no significant difference between pre-hunt, hunt, and post-hunt study periods (F = 0.040, df = 24, P = 0.961) (Table 1).

Movement

For average overall movement (per hour) between pre-hunt, hunt, and post-hunt periods [261 (SE = 87) m, 198 (SE = 66) m, 194 (SE = 65) m, respectively], the difference was nearly significant between pre-hunt and other periods (F = 3.270, df = 24, P = 0.055). I detected a significant decrease in movement during the dawn hours (F = 6.284, df = 24, P = 0.006); pre-hunt and hunt periods differed (P = 0.022), pre-hunt and post-hunt periods differed ($P = 0.010$), and hunt and post-hunt periods were similar ($P = 0.930$). Also, I detected a significant decrease in movement during the day hours ($F = 11.060$, $df = 24$, $P < 0.001$); pre-hunt and hunt periods differed ($P = 0.001$), pre-hunt and post-hunt periods differed ($P = 0.002$), and hunt and post-hunt periods were similar ($P = 0.961$) (Table 2). I detected no significant difference for hourly movement between study periods during the dusk ($F = 0.113$, $df = 24$, $P = 0.893$) and night ($F =2.229$, $df = 24$, $P = 0.129$) hours (Table 2).

Micro-scale movement (5, 20-minute fix interval) by adult males was examined in relationship to known hunter locations. I documented 23 occasions during the 2006 and 2007 hunting season when hunters could potentially have interacted with adult male white-tailed deer. In 9 instances, there was a definitive change in movement by the deer when disturbed by hunters; and when pronounced flight response occurred ($n = 7$), average distance traveled was 257 meters.

Activity

I detected a significant decrease in activity during the day hours ($F = 6.289$, $df = 24$, $P = 0.006$); pre-hunt and hunt periods differed ($P = 0.016$), pre-hunt and post-hunt periods differed ($P = 0.012$), and hunt and post-hunt periods were similar ($P = 0.994$) (Table 3). During dusk hours, a nearly significant decrease ($F = 2.655$, $df = 24$, $P = 0.091$) in activity between pre-hunt and hunt periods ($P = 0.075$) was detected (Table 3). During the dawn ($F = 2.210$, $df = 24$, $P = 0.132$) and night ($F = 1.027$, $df = 24$, $P = 0.373$) hours, there was no significant difference in activity between study periods (Table 3). I detected no significant difference in overall activity levels between study periods ($F = 0.815$, $df = 24$, $P = 0.132$) (Table 3).

Vulnerability

I detected no significant difference in vulnerability between pre-hunt [9% (SE = 3%)], hunt [10% (SE = 3%)], and post-hunt [8% (SE = 3%)] periods (F = 0.047, df = 24, P = 0.954). Also, there was no statistical difference in vulnerability during the dawn (F = 0.091, df = 24, P = 0.913), day (F = 0.194, df = 24, P = 0.825), or dusk (F = 0.320, df = 24, P = 0.729) hours between study periods (Table 4).

Refuge Use

Refuge use was estimated using data from 8 of the 9 useable males. I omitted 1 male white-tailed deer because its home range never included the designated refuges. No significant difference between the percentage of overall refuge use during pre-hunt [12% (SE = 4%)], hunt [17% (SE = 6%)], and post-hunt [17% (SE = 6%)] periods was detected (F = 0.397, df = 21, P = 0.677). I detected no significant difference in refuge use during the dawn (F = 1.220, df = 21, P = 0.315), day (F = 0.556, df = 21, P = 0.582), dusk (F = 0.555, df = 21, P = 0.582), or night (F = 0.045, df = 21, P = 0.956) hours between study periods (Table 5).

Polygon centroid to nearest road and hunting stand

I omitted 3 of the 9 males from analysis because >50% of the fixes were outside the boundaries of Chesapeake Farms. For the 6 remaining deer, I detected no significant difference in distance from home range polygon centroids to nearest roads (F = 0.674, df = 15, P = 0.524) and hunting stands (F = 0.015, df = 15, P = 0.985) during the pre-hunt, hunt, and post-hunt periods (Table 6). Also, no significant difference in distance from core area polygon centroids to nearest roads (F = 0.694, df = 15, P = 0.515) and hunting stands

(F = 0.121, df = 15, P = 0.887) during the pre-hunt, hunt, and post-hunt periods was detected (Table 6).

Mean center to nearest road and hunting stand

Using data from the 6 males that spent >50% of time on Chesapeake Farms, I detected no difference in distance from arithmetic mean center of pre-hunt [173 (SE = 71) m], hunt [237 (SE = 97) m], and post-hunt [230 (SE = 94) m] fixes to nearest road (F = 0.566, df = 15, P = 0.580). Also, there was no statistical difference in distance from mean center of pre-hunt [181 (SE = 74) m], hunt [223 (SE = 91) m], and post-hunt [188 (SE = 77) m] fixes to nearest hunting stand (F = 0.279, df = 15, P = 0.760).

Fix to nearest hunting stand

Using the 6 deer that lived predominantly inside Chesapeake Farms' boundaries, I detected no significant difference in distance from each top-hour fix to the nearest hunting stand during the dawn (F = 0.732, df = 15, P = 0.497), day (F =0.665, df = 15, P = 0.529), dusk (F = 0.262, df = 15, P = 0.773), or night (F = 1.008, df = 15, P = 0.388) hours between study periods (Table 7). For overall pre-hunt [320 (SE = 131) m], hunt [273 (SE = 111) m], and post-hunt [282 (SE = 115) m] periods, I detected no significant difference (F = 0.756, df = 15, P = 0.487) for fix distances to nearest hunting stands.

Discussion

Although poor satellite geometry (high PDOP values), timing errors, ephemeris errors, atmospheric interference, multipath signals, and signal noise can decrease GPS location accuracy (Graves and Waller 2006), distance and direction of GPS collar location error is approximately normally distributed (Moen et al. 1997, Brooks et al. 2008). Because fine-scale habitat use was not the focus of my objectives, I decided against differentially correcting collar locations (Dussault et al. 2001, Rempel and Rodgers 1997, Hebblewhite et al. 2007). Although Tomberlin (2007) reported mean location errors ranging from 4.3 to 37.7 meters depending on habitat type, differential correction marginally improves location accuracy, but is not mandatory in studies with larger sample sizes (>5,000 locations) (Graves and Waller 2006).

D'eon and Delparte (2005) cautioned against systematically culling data from studies based on PDOP, dimensionality, and altitude thresholds, but other studies recommended removing locations with high probability of large error (Rempel et al. 1995, Rempel and Rodgers 1997). Because number of fixes per animal was sufficient to absorb a 10-20% reduction in data, I decided to remove low quality fixes because outlying locations might significantly influence outer kernel contours (Horne and Garton 2006). Using the same altitude, PDOP, and dimensionality thresholds as my study, Tomberlin (2007) deleted more fixes from wooded habitat (13%) than open fields (0%). This could have under-represented use of wooded habitat in the study. Additionally, because collar fix success is not constant through time and space (Moen et al. 1997), systematic bias in collar performance might have influenced results of the study, particularly refuge use. Because fix success is negatively correlated with tree density, basal area, and canopy cover (Rempel et al. 1995, Di Orio et al. 2003, Rempel and Rodgers 1997, Cargnelutti et al. 2007, Hansen and Riggs 2008), habitats characterized by thick, wooded cover are likely under-represented and more open habitats are over-represented in datasets. Consequently, refuge use rates might have been underestimated and shifts in polygon centroids and mean center of fixes towards interior forest habitats might be disguised. Also, because animals are typically bedded and stationary while utilizing refuge areas, rates might be further underestimated because fix success is positively correlated with mean movement rates (Graves and Waller 2006) and bedded deer experience lower fix rates than active deer (Bowman et al. 2000).

I estimated home range (95%) and core area (50%) contours with a fixed kernel density estimator. Although true contours are usually overestimated (Naef-Daenzer 1993, Worton 1995, Seaman and Powell 1996) and estimates are sensitive to the smoothing parameter (Worton 1995, Horne and Garton 2006), kernel estimators are the most unbiased home range estimators (Borger et al. 2006, Seaman and Powell 1996). For studies where home range and core area estimates must be extremely accurate and precise, least squares cross-validation, likelihood cross-validation, and other methods are recommended for choosing the appropriate smoothing parameter (Worton 1989, Seaman et al. 1999, Borger et al. 2006, Horne and Garton 2006). However, the intent of my project was not to compare home range and core area sizes between studies, and an ad hoc choice of the smoothing parameter was deemed appropriate (Worton 1989, Horne and Garton 2006).

I detected a significant decrease in adult male white-tailed deer movement and activity during the hunting season; however, this was not surprising because the hunting season corresponded with the post-breeding period when such changes would be expected (Tomberlin 2007). Males are physically stressed from the rigors of breeding season and reduce movement and activity after the majority of females have been fertilized (Tomberlin 2007). In high density populations with unbalanced sex ratios, a pronounced secondary rut (as unbred females enter their second estrus cycle) could extend elevated levels of movement and activity and further disguise influences of hunting pressure on white-tailed deer behavior (Knox et al. 1988).

Interestingly, adult male white-tailed deer used Chesapeake Farms as a refuge in the context of the larger landscape. Hunting pressure was much higher on surrounding properties, and males (n = 3) that lived predominantly (>50% pre-hunt fixes not inside Chesapeake Farms' boundary) off Chesapeake Farms before hunting season shifted their home ranges and core areas to center more on Chesapeake Farms when hunting season started (Fig. 2). Deer that lived predominantly on Chesapeake Farms (n = 6) throughout the study did not exhibit any disproportionate avoidance of roads or hunting stand locations suggesting that the amount of hunting pressure exerted by hunters (on Chesapeake Farms) was insufficient to induce changes in deer behavior. Interestingly, adult males did not utilize core areas at higher rates during the hunt period. During the 2006 (and 2007) firearms season at Chesapeake Farms, hunting pressure was 0.05 hours hunted/ha/day (max: 0.12) and 0.92 hunters/km^2/day (max: 2.31) respectively, far lower than other studies (Murphy 1962, Kennedy 1974, Cue and Langenau 1979, Diefenbach et al. 2005) and the 0.45 hours/ha/day threshold reported by Root et al. (1988).

Shorter time intervals (5, 20-minutes) were valuable for analyzing fine-scale movements by adult males during hunting season, but using those same intervals for movement per hour estimates would have overestimated true movement because perceived movement between shorter time intervals could be GPS error around a stationary bedded deer. In a case with a bedded deer, GPS location error would be additive, and longer time intervals help minimize this concern (Heezen and Tester 1967, Pepin et al. 2004). Dawn and day movements significantly decreased during the hunting season, but dusk and night movements remained stable indicating that deer returned to bedding areas earlier in the morning, but movement to feeding areas during dusk hours was not suppressed. Higher vulnerability rates during crepuscular hours reflected the peak in deer movement between feeding and bedding areas at dawn and dusk. Also, many hunting stand locations were located in close proximity to roads and/or open fields, and deer were least vulnerable during day hours when utilizing interior forest habitats.

Examination of the fine-scale response of adult male white-tailed deer to known hunter locations revealed that disturbances by hunters or hunter transportation produced a behavioral response in only half of the encounters documented. Flight responses were temporary, and no change in daily habits or shifts in home ranges or core areas were observed. In fact, adult males were commonly flushed from fields near dusk or bedding areas during mid-afternoon only to resume activities in the same location mere hours later (Fig. 3). Hunting disturbances never pushed deer out of their home range (Naugle et al. 1997, Vercauteren and Hygnstrom 1998), and flight distances never exceeded 550 meters.

A fundamental difficulty with the study was the low number of study animals. Greater than 50% of the collared deer (n=19) had to be removed from the study due to mortality (n=7) or collar malfunction (n=3), greatly reducing the inherent statistical power of the study. In addition, reducing sample size in the polygon centroid, mean center, and fix distance to stand analyses resulted in even lower precision. Polygon centroid and mean center measures are geometrically determined, and although they do not necessarily fall inside the area of an animal's activity (because core areas are often multi-modal; Inglis et al. 1979), they can be effectively used to indicate shifts towards or away from areas of interest (Hayne 1949, Neft 1966, Heezen and Tester 1967). In future studies, it would be advantageous to study the impact of hunting pressure on white-tailed deer where hunting season occurred before or after breeding season when white-tailed deer behavior changes considerably.

Conclusion

The degree of hunting's influence on white-tailed deer behavior was largely dependent on how intensely hunting pressure was exerted on the population. At Chesapeake Farms, where hunting pressure was lower than on surrounding properties, there was evidence that it acted as a pseudo-refuge within the larger landscape. Although adult male movement and activity decreased from pre-hunt to the hunt and post-hunt periods, this was probably more attributable to hunting season overlapping with the post-breed period. Because deer did not exhibit any notable avoidance of hunted areas or perceptibly change daily habits in response to being hunted, results indicated the current levels of hunting pressure on Chesapeake Farms were not sufficient to induce considerable change in adult male white-tailed deer behavior.

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Table 1. Home range size, core area size, and intensity values for pre-hunt, hunt, post-hunt, and overall study periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses.

	Overall	Pre-hunt	Hunt	Post-hunt	P-value
Home range	386 (129)	306 (102)	261 (87)	263 (88)	0.633
Core area	81 (27)	71 (24)	59 (20)	61 (20)	0.404
Intensity	0.22 (0.07)	0.24 (0.08)	0.23 (0.08)	0.24 (0.08)	0.961

Table 2. Movement per hour (meters) during dawn, day, dusk, and night between pre-hunt, hunt, and post-hunt study periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses.

	Pre-hunt	Hunt	Post-hunt	P-value
Dawn	337 (112)	210 (70)	193 (64)	0.006
Day	141 (47)	71 (24)	76 (25)	<0.001
Dusk	291 (97)	282 (94)	299 (100)	0.893
Night	275 (92)	227 (76)	208 (69)	0.129

Table 3. Mean activity values (y-axis sensor) during dawn, day, dusk, and night between pre-hunt, hunt, and post-hunt study periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses.

	Pre-hunt	Hunt	Post-hunt	P-value
Dawn	39 (13)	26 (9)	27 (9)	0.132
Day	25 (8)	15 (5)	14 (5)	0.006
Dusk	43 (14)	28 (9)	36 (12)	0.091
Night	32 (11)	24 (8)	25 (8)	0.373
Overall	32 (11)	22 (7)	24 (8)	0.132

Table 4. Vulnerability values during dawn, day, and dusk between pre-hunt, hunt, and post-hunt periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses.

	Pre-hunt	Hunt	Post-hunt	P-value
Dawn	12% (4%)	12% (4%)	11% (4%)	0.913
Day	6% (2%)	8% (3%)	5% (2%)	0.825
Dusk	11% (4%)	10% (3%)	12% (4%)	0.729

Table 5. Refuge use during dawn, day, dusk, and night between pre-hunt, hunt, and post-hunt periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses

	Pre-hunt	Hunt	Post-hunt	P-value
Dawn	12% (4%)	24% (8%)	28% (10%)	0.315
Day	24% (8%)	37% (13%)	38% (13%)	0.582
Dusk	16% (6%)	28% (10%)	26% (9%)	0.582
Night	3% (1%)	3% (1%)	2% (1%)	0.956

Table 6. Mean distance (meters) from nearest road and hunting stand to home range (95%) and core area (50%) polygon centroids between pre-hunt, hunt, and post-hunt study periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses.

		Pre-hunt	Hunt	Post-hunt	P-value
Home range	To nearest road	191 (78)	244 (100)	298 (122)	0.524
	To nearest stand	188 (77)	192 (78)	196 (80)	0.985
Core area	To nearest road	214 (88)	195 (79)	151 (61)	0.515
	To nearest stand	216 (88)	201 (82)	187 (76)	0.887

Table 7. Mean distance (meters) from individual fix to nearest stand between pre-hunt, hunt, and post-hunt study periods, Chesapeake Farms, Maryland, 2006-2007. Standard error in parentheses.

	Pre-hunt	Hunt	Post-hunt	P-value
Dawn	310 (126)	250 (102)	259 (106)	0.497
Day	315 (128)	260 (106)	308 (126)	0.529
Dusk	309 (126)	270 (110)	294 (120)	0.773
Night	331 (135)	281 (115)	271 (111)	0.388

Figure 1. Designated refuges located on Chesapeake Farms, Maryland, 2006-2007.

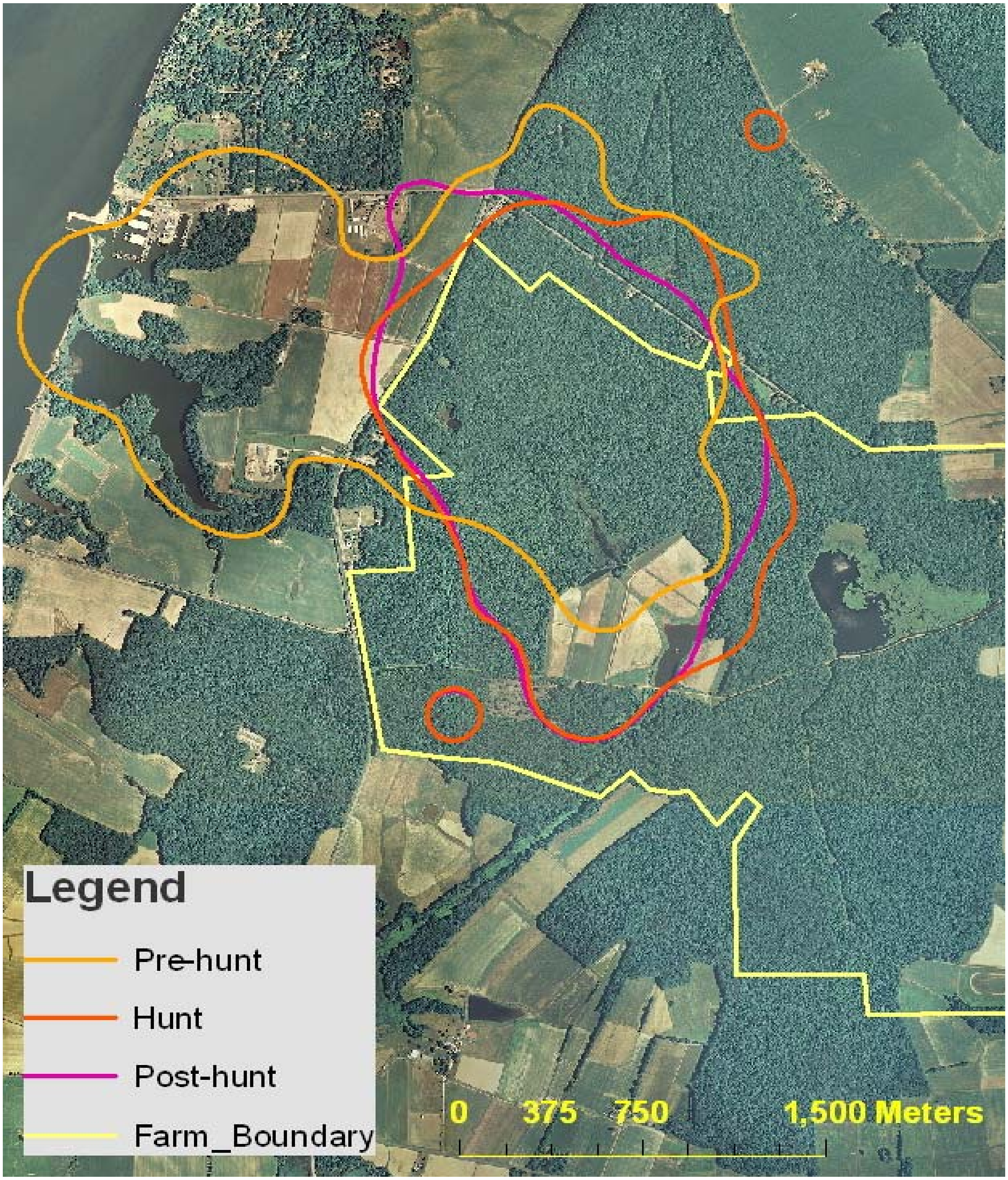

Figure 2. A 2.5-year-old male white-tailed deer shifts home range increasing onto Chesapeake Farms property from pre-hunt to hunt and post-hunt periods, Chesapeake Farms, Maryland, 2007.

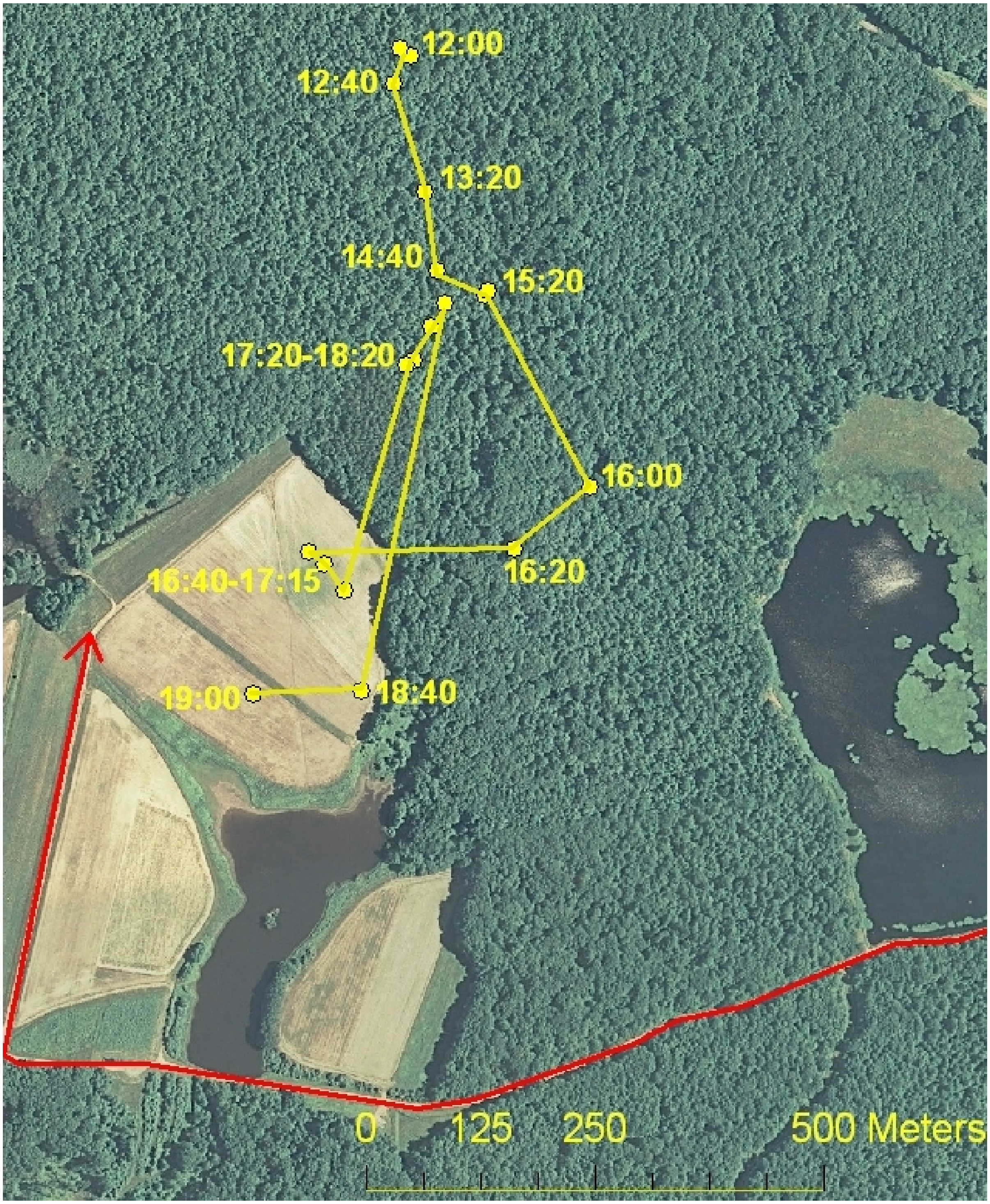

Figure 3. Flight response of 3.5-year-old male white-tailed deer to hunter transportation (red line) entering fields at 17:15, Chesapeake Farms, Maryland, 27 November 2006.

INVESTIGATION OF ADULT MALE WHITE-TAILED DEER EXCURSIONS OUTSIDE THEIR HOME RANGE

Abstract

Although male and female white-tailed deer (*Odocoileus virginianus*) exhibit high site fidelity throughout the year, individuals – particularly adult males - occasionally leave their home ranges on short excursions during the fall and winter months. It is difficult to discern motives for these extraneous movements, but excursions are likely the function of the breeding season, shifting locations of food sources, limited security and escape cover, or human disturbances. From 2003-2007, I examined GPS collar locations of 32 adult male white-tailed deer at Chesapeake Farms, Maryland. From 24 September to 31 January, excursions (n = 30), defined as movements lasting longer than 6 hours and venturing at least 0.5 miles from 95% kernel home range contour, were examined relative to possible motives related to breeding, season, and hunting. 53% (n=17) of adult males made at least one excursion outside their home range during the pre-breed 2 or breeding periods. Based on the seasonal timing of excursions, results indicate that breeding season-related motives were likely the driving force behind most adult male white-tailed deer excursions, whereas hunting was not a probable cause.

Introduction

Prior to the breeding season, adult male white-tailed deer (*Odocoileus virginianus*) live in loose assemblages (i.e., bachelor groups) and females live within family groups led by a matriarchal doe (Hawkins and Klimstra 1970). Female groups usually include offspring from the previous and current year (Hawkins and Klimstra 1970). As the breeding season approaches, more than half of yearling males disperse from their natal range (Rosenberry et al. 1999; McCoy et al. 2005; Shaw 2005), and adult males separate and isolate themselves (Thomas et al. 1965, Hawkins and Klimstra 1970, Rosenberry 1997, Rosenberry et al. 2001).

GPS data from previous studies at Chesapeake Farms, Maryland, indicated that some males travel significant distances outside their normal home range for short periods throughout the fall and winter, with most of these travels occurring immediately prior to and during the breeding season (Tomberlin 2007). The excursions lasted 6 – 28 hours, and bucks quickly returned to their home range. Occasionally, adult males ventured outside their normal home range during the rut – presumably searching for receptive females (Hawkins and Klimstra 1970, Guyse 1978, Hosey 1980). Also, white-tailed deer temporarily leave their home range to avoid hunting pressure and other disturbances (Hood and Inglis 1974, Naugle et al. 1997, Vercauteren and Hygnstrom 1998).

As male breeding activities intensify (i.e., rubbing, scraping, sparring, and searching for estrous females) and movement and home ranges increase (Guyse 1978, Hosey 1980, Tomberlin 2007), females concentrate movement and scent markings within their core areas as estrus approaches (Fraser 1968, Marchinton 1968, Ivey and Causey 1981, Nelson and Mech 1981, Holzenbein and Schwede 1989). Females might increase the chance of a suitable mate detecting her presence by increasing activities within a small area (Holzenbein and Schwede 1989). During the breeding season, males often pursue females that show no immediate indication of being in estrus (Richardson and Petersen 1974), and studies have noted a dramatic increase in female movement and activity before estrus begins (Ozoga and Verme 1975, Holzenbein and Schwede 1989). As a female enters estrus, a male stimulated by olfactory and behavioral cues, separates the female from the matriarchal herd, and tenaciously follows her for 1-6 days (Crawford 1962, Brown 1971, Holzeinbein and Schwede 1989). After being tended and bred, the female returns to normal movement and activity levels within a couple of days (Ozoga and Verme 1975, Holzenbein and Schwede 1989).

In a deer population with a relatively higher percentage of breeding males, females should increase fitness by concentrating movement in their core area (Labisky and Fritzen 1998). Conversely, if a female is in estrus and breeding has not occurred, a female might initiate a search strategy to find a mate during her 24-hr. window of receptivity (Holzenbein and Schwede 1989). Excessive movement of females during the rut might indicate poor male breeding performance in a herd (Holzenbein and Schwede 1989). Immediately prior to estrus, increases in female movement might incite a male to chase her and instigate male-male competition (Cox and Boeuf 1977). By luring a courting male into a chase and venturing outside her core area, the female might attract attention from other potential mates. Once engaged in the chase, males might easily be led outside their home range and into unfamiliar territory, possibly bringing multiple males together and stimulating intrasexual competition (Emlen and Oring 1977, Cox and Boeuf 1977). The female selectively chooses her mate, and once the breeding pair is formed, movement and activity decreases until the female returns to her core area and resumes normal activities, and the male resumes searching for receptive females (Cox and Boeuf 1977).

Excursions by adult male white-tailed deer are a phenomenon not easily studied because of their lack of predictability and difficulty of detection using conventional telemetry equipment. Research shows that such movements are exploratory either searching for estrous females or locating new food sources (Hawkins and Klimstra 1970, Moore and Marchinton 1974, Guyse 1978, Hosey 1980); or movements might be a male being lead by an estrous female back to her core area (Cox and Boeuf 1977, Holzenbein and Schwede 1989), a male leading a receptive mate away from intrasexual breeding competition (Moore and Marchinton 1974), or female incitation of male competition (Cox and Boeuf 1977). Movements might be caused by any one of these motives or for other unknown reasons.

Objectives were to 1) analyze adult male white-tailed deer excursions during the fall and winter of 2003-2007 and 2) combine female movement data from GPS collars with similar data from adult males and check for overlapping excursions.

Methods

Using data from 32 adult male white-tailed deer during 2003-2007, I documented excursions outside of fixed kernel home ranges (95% volume). These movements were required to exceed 0.5 miles from outer home range contour, encompass 6 or more continuous hours, and needed to occur between 24 September and collar release date (individual-specific). Each movement was individually examined and classified as exhibiting either basically continuous movement or a defined immobile lull during the excursion outside the animal's home range contour. Repeated excursions by the same individual were noted and analyzed independently.

I defined 24 September – 14 October as pre-breed 1, 15 October – 4 November as pre-breed 2, 5 November – 25 November as breeding, 26 November – 16 December as post-breed, and 17 December – collar release date as winter. During 2003-2007, the Maryland 2-week firearms season was conducted from 29 November – 13 December, 27 November – 11 December, 26 November – 10 December, 25 November – 9 December, and 24 November – 8 December, respectively (Tomberlin 2007). I plotted excursions to the following timeline (pre-breed 1 to winter) to examine possible motives for extraneous movements. Specific motives for adult male white-tailed deer excursions include resource explorations (pre-breed 1, post-breed, and winter), searching for receptive females (pre-breed 2 and breeding), chasing females (pre-breed 2 and breeding), breeding estrous females (breeding) or hunting avoidance movements (during firearms season).

During May-August 2006, 14 female white-tailed deer (≥ 1.5-year-old) were collared to study movement during the breeding and fawning seasons (J. Kolodzinski, unpublished M.S. data, University of Georgia). GPS collars were programmed to collect 45-minute interval (1 October – 31 January, 1 April – 31 July) and 1-hour interval (1 February – 31 March, August 1 – September 30) fixes for 365 days following deployment. To further investigate adult male excursions during the white-tailed deer breeding season, I attempted to match female movements to adult male excursions during the pre-breed 2 and breeding periods.

Results

Thirty adult male white-tailed deer excursions were documented, with the highest number (n=14) occurring during the breed period (Fig. 1). Although the number of study animals steadily decreased because of mortality or collar malfunction (Fig. 2), 53% (n=17) of the adult bucks made at least one excursion (Fig. 3). Interestingly, 47% (n=14) of excursions were characterized by continuous movement (Fig. 4) and 53% (n=16) by periods of little to no movement (Fig. 5). Further, there was no clear relationship of excursion type within periods and no collared female movements matched the 30 adult male excursions.

Discussion

Greater than half of the GPS collared adult male white-tailed deer on Chesapeake Farms made excursions outside of their home range between the pre-breed 1 and winter period. With 73% (n = 22) of excursions occurring during the pre-breed 2 and breeding periods, the distribution of extraneous movements by adult male white-tailed deer indicated that breeding season activities were the most common cause of these movements. However, when the raw number of excursions were adjusted for by the number of animals remaining alive in the study, as many deer made excursions in the winter period (25%) as during the pre-breed 2 period (26%). Because the deer population at Chesapeake Farms was characterized by older age class males and a balanced sex ratio, the secondary rut (when un-bred females enter their second estrus cycle) was probably insignificant compared to other regions or properties (Geist 1971, Clutton-Brock et al. 1997). Therefore, after the principal breeding period, it is likely that breeding season-related movements constituted a minor component of post-breed excursions.

Excursions characterized by continuous movement or associated with a period of no movement suggest that some motives are more likely than others. For example, a male searching unsuccessfully for receptive females outside his home range would likely continue moving through unfamiliar territory before returning to his normal home range. However, a buck tending a receptive doe might attempt to isolate her from intraspecific competition and mate with her as many times as possible (Hirth 1977). It is purely speculative, but repeated excursions by the same male might suggest re-visiting a female group to check for receptive mates or utilizing a select food source that was discovered by previous experiences. I documented only 3 repeat excursions (1 during pre-breed 2 period and 2 during breeding period), thus it would appear that most excursions are not explorations for new food sources as one or two trips to a distant food source would not justify the potential risk and energy expenditure of those excursions.

Although 4 excursions (1 in 2003, 2 in 2004, 1 in 2005) were documented during Maryland’s 2-week firearms season, I am doubtful that movements were prompted by hunting disturbance. Based on fine-scale movement data collected during the 2006 (20-minute fix interval) and 2007 (5-minute fix interval) firearms season, I compared adult male movement during daylight hours to known hunter locations (Chapter 1). Whether disturbed by hunters or vehicles, flight distances never exceeded 600 meters, and no deer left its home range in response to hunting-related disturbances (Chapter 1). Especially where security and escape cover were limiting factors in a landscape, some white-tailed deer temporarily left their home range in direct flight response to hunting and other intrusive activities (Altmann 1958, Hood and Inglis 1974, Lagory 1987, Naugle et al. 1997). However, based on low levels of hunting pressure, abundant cover at Chesapeake Farms, and flight distance data from adult males during 2006 and 2007, hunting was an unlikely cause for adult male excursions.

Although 2 adult males utilized multiple home ranges or exhibited evidence of adult dispersal, movements in transit between home ranges were not included in analyses. Webb et al. (2007) reported that 15% of adult male white-tailed deer (usually 2.5-3.5-year-olds) disperse and permanently vacate their natal range. In high quality deer habitat (i.e., habitat at Chesapeake Farms, Maryland), there was no compelling evidence in the literature that would suggest legitimate reasons for maintaining 2 separate home ranges and the behavior may simply be explained as the idiosyncrasies of a few individuals (<10%). In more northern latitudes, where white-tailed deer populations migrate between summer and winter ranges, special caution must be taken to avoid misclassifying migratory movements as extraneous excursions (Tierson et al. 1985, Brinkman et al. 2005, Nixon et al. 2008).

Yearling males are disproportionately vulnerable during lengthy dispersal movements through unfamiliar territory (Roseberry and Klimstra 1974, Nelson and Mech 1986). Similarly, adult males venturing on excursions are highly vulnerable to hunter harvest [73% (n=22) of excursions occurred partially or completely during daylight hours], antagonistic encounters with competing males, and other mortality factors in unfamiliar territory (Swenson 1982). In 2005, a 5.5-year-old male was killed in a vehicle collision while crossing an unfamiliar, busy 2-lane road, and in 2006, a 3.5-year-old male was superficially wounded by an archery hunter while making an excursion.

None of the female (n = 14) movements mirrored any adult male excursions during the 2006 pre-breed 2 and breeding periods. Based on the difficulty (having too few collared deer in the population to maximize likelihood of matching excursions between males and females) I experienced conducting this research on a high density deer population at Chesapeake Farms and assuming that excursions occur at relatively similar frequencies and for the same motives under a different herd structure, I recommend that low to moderate density populations be studied in the future, and that researchers collar as many individuals of both sexes as possible within a relatively concentrated area. Although in free-ranging white-tailed deer populations this is difficult, the probability that a limited number of males directly interacts with a limited number of females during the breeding season in a high density population (such as Chesapeake Farms) is very low.

To keep benign wandering movements and erroneous locations from being included as excursions, I chose rigorous criteria for identifying true excursions. The inherent nature of a fixed kernel home range dictates that a certain percentage of locations will be located outside the 95% contour. In studies examining extraneous movements and excursions, caution must be taken to enforce strict guidelines and case-by-case examination of possible excursions.

Conclusion

It appears the white-tailed deer breeding season motivates the majority of adult male excursions, but it is difficult to hypothesize plausible motives for excursions taking place during other periods, especially the pre-breed 1 and winter periods. At Chesapeake Farms, excursions put individual deer at risk of mortality (particularly hunter harvests and vehicle collisions), but movements into unfamiliar environments do not occur frequently enough to drastically impact the survival rate of older age class cohorts. Researchers recognize that yearling male dispersal plays a major role in landscape ecology processes such as gene flow and disease transmission (Rosenberry et al. 1999, McCoy et al. 2005, Schauber et al. 2007); however, the role of adult male white-tailed deer excursions in these same processes is commonly overlooked. In future research, I recommend that low to moderate density populations be studied because of the higher probability of matching common movements between sexes.

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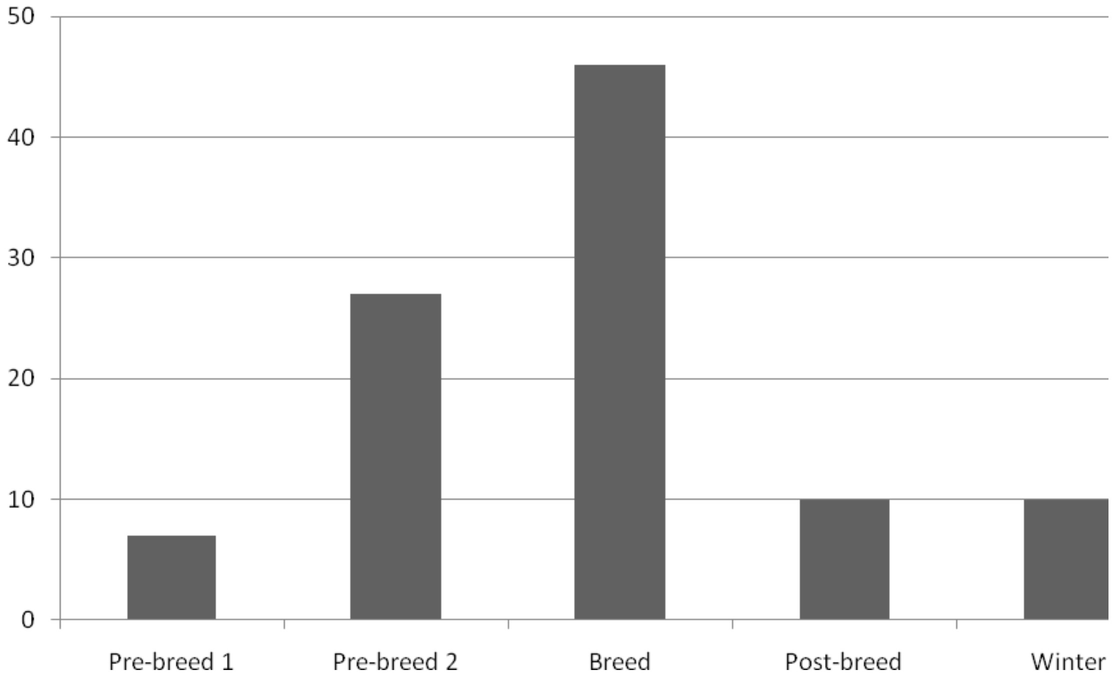

Figure 1. Percentage of adult male white-tailed deer excursions by study period, Chesapeake Farms, Maryland, 2003-2007.

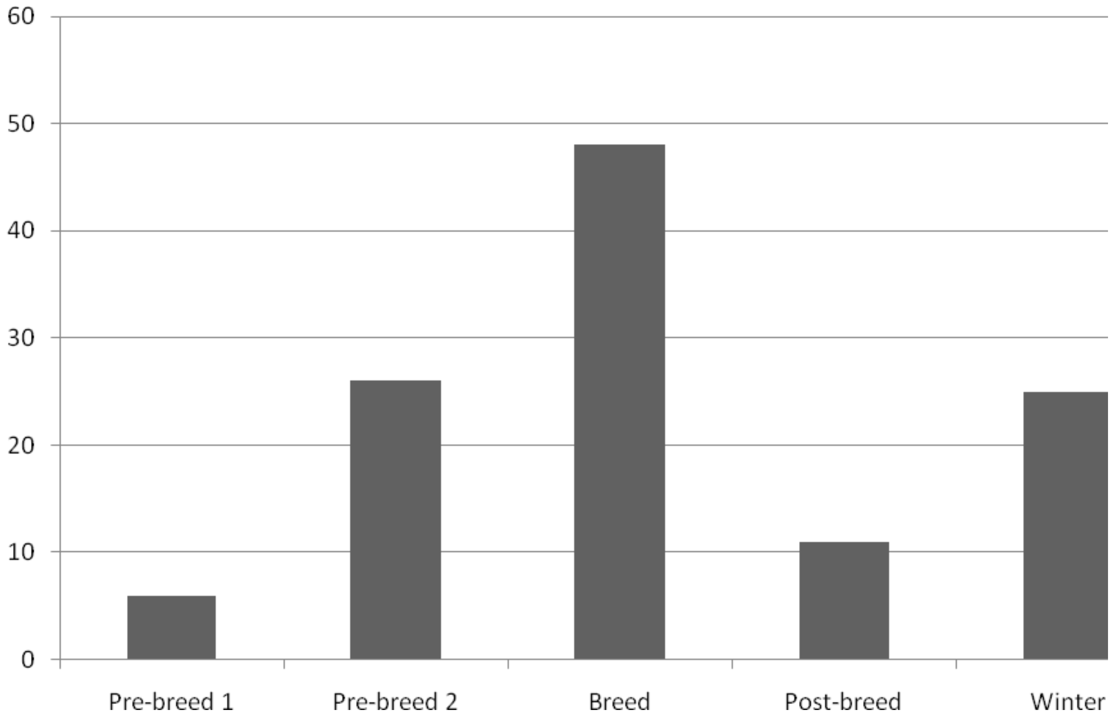

Figure 2. Percentage of adult male white-tailed deer making excursions during each study period, Chesapeake Farms, Maryland, 2003-2007.

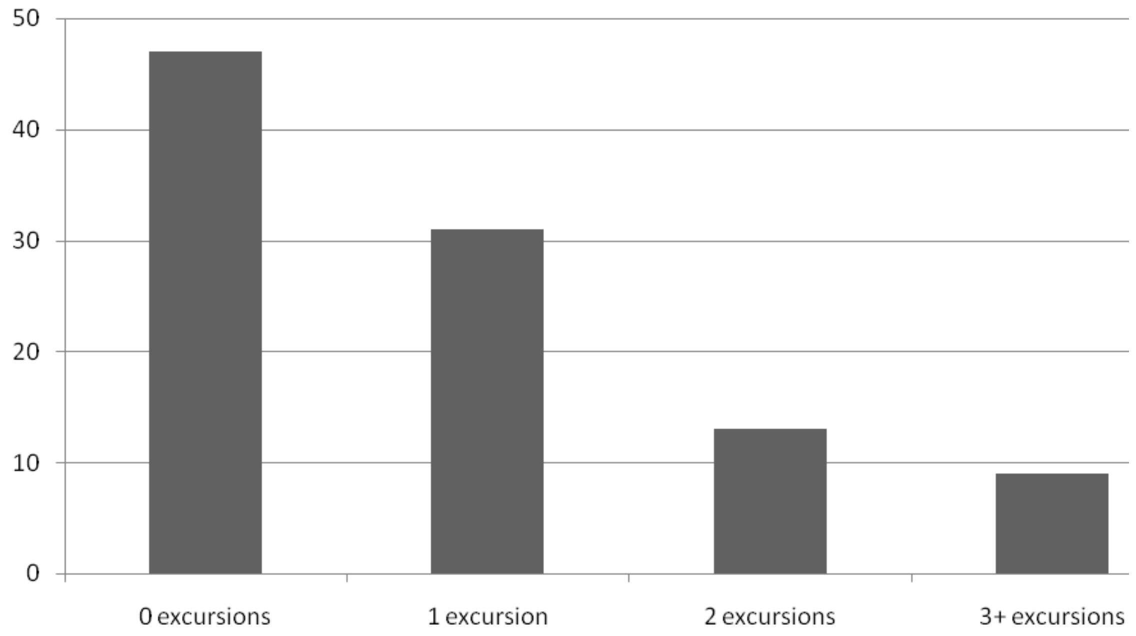

Figure 3. Percentage of adult male white-tailed deer making 0, 1, 2, or 3+ excursions, Chesapeake Farms, Maryland, 2003-2007.

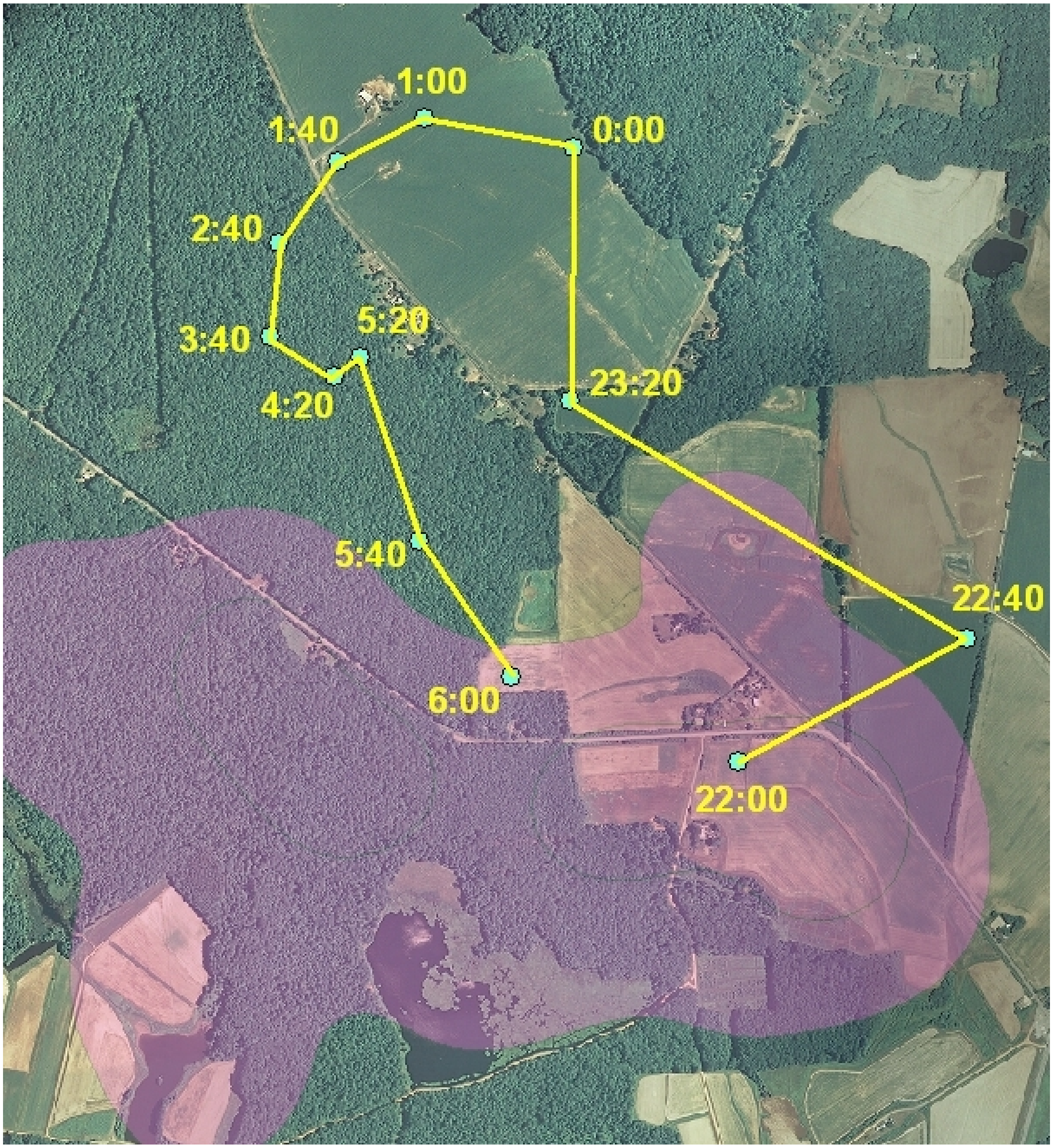

Figure 4. Continuous excursion by 3.5-year-old adult male white-tailed deer, Chesapeake Farms, Maryland, 8-9 November 2006 (22:00 – 6:00). 95% fixed kernel home range represented by shaded area.

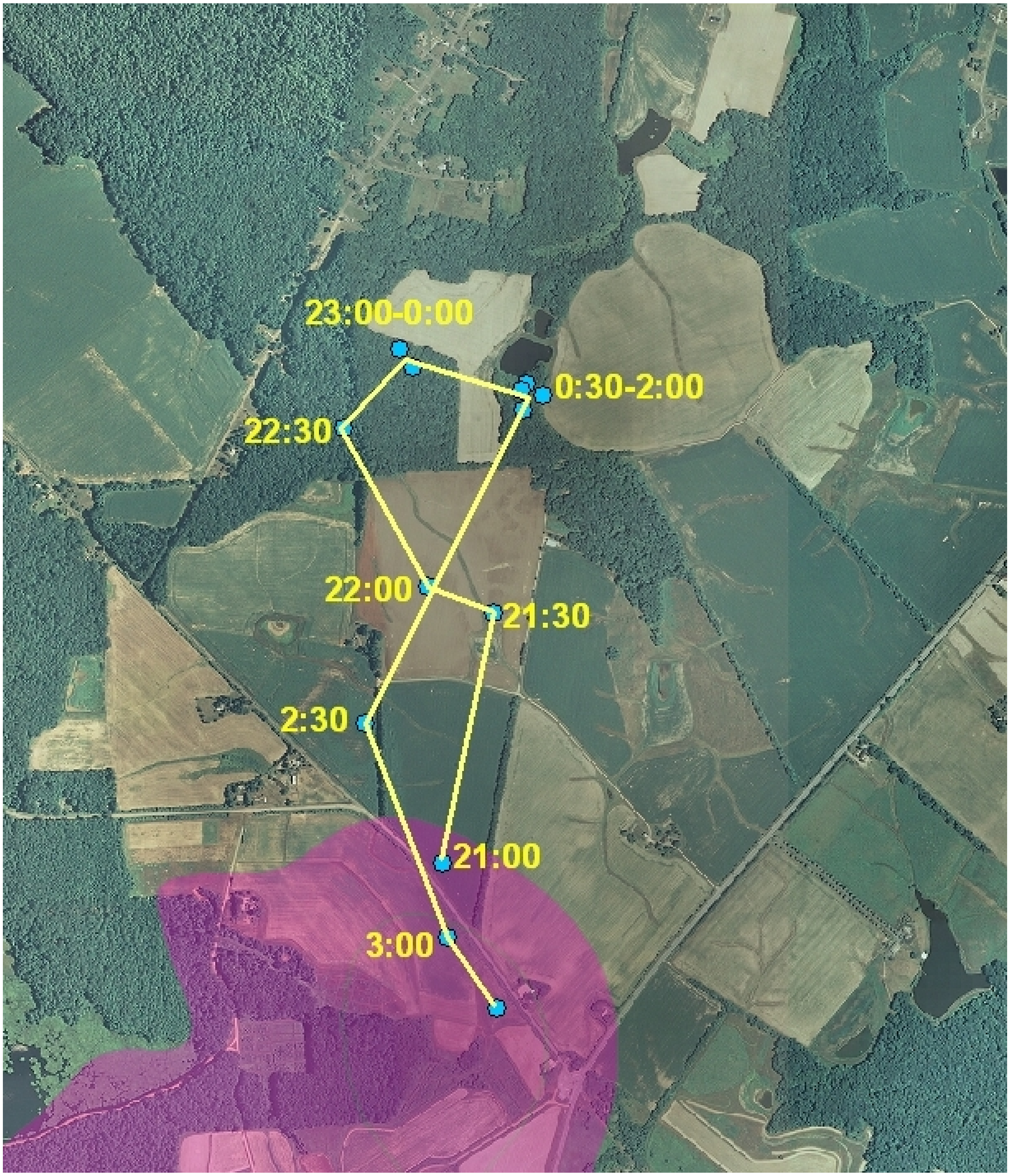

Figure 5. Excursion with a lull by 3.5-year-old adult male white-tailed deer, Chesapeake Farms, Maryland, 12-13 November 2007 (21:00 – 3:00). 95% fixed kernel home range represented by shaded area.

IMPROVEMENT OF A CATCH-PER-UNIT-EFFORT ESTIMATOR FOR WHITE-TAILED DEER POPULATIONS

Abstract

To enhance the effectiveness and user-friendliness of an existing catch-per-unit-effort (CPUE) technique, I converted the original FORTRAN (IBM, Armonk, NY) code to JMP scripting language (JSL) (SAS Institute, Cary, North Carolina), modified the parameter constraints, and took advantage of optimization routines that improved convergence properties. I estimated an antlered white-tailed deer (*Odocoileus virginianus*) population on Chesapeake Farms, Maryland, from 1981-2006 using the new CPUE technique, validated it by comparison to previous CPUE and reconstructed estimates of the same population, and tested the usefulness of the new model in traditional and quality deer management paradigms under a 1-week versus 2-week hunting season. The user-friendly CPUE-JMP technique consistently underestimated reconstructed values by 20-25%, but produced long-term trends suitable for many big-game management applications.

Introduction

An accurate estimation of population abundance is critical to understanding mortality and recruitment parameters, analyzing dispersal mechanisms, or determining if management and harvest strategies have been successful (e.g., reducing a herd to cultural/biological carrying capacity or increasing the number of individuals in older age classes) (Caughley 1977, Conner 1988, Novak et al. 1991, Rosenberry et al. 1999, Shaw et al. 2006). Catch-per-unit-effort techniques (CPUE) estimate abundance at the beginning of a time interval and can be readily applied to harvested populations under the following conditions: 1) the rate of catch is proportional to the level of effort expended, 2) an increase or decrease occurs in the population, and 3) population change is known (Lancia et al. 1996).

Given the 3 conditions are met, 2 basic assumptions of CPUE population estimations are a closed population (except for known removals or additions) and an equal rate of catchability for all individuals within the population (Lancia et al. 1996). Short sampling periods minimize concerns over the closed population assumption (Lancia et al. 1996), but environmental fluctuations, behavioral responses, and heterogeneity due to inherent individual characteristics can violate the equal catchability assumption (Lewis and Farrar 1968, Miller and Mohn 1993). Short, closely controlled hunting seasons, in which hunters provide accurate effort and catch data, lend themselves to CPUE estimation. Also, a short hunting season decreases the likelihood of heterogeneous catchability attributable to behavioral response of game to hunting pressure and lessens the occurrence of unknown natural mortality, crippling losses, illegal hunting mortality, births, immigration, and emigration during the time interval (Lancia et al. 1988, Bishir and Lancia 1996).

Within the context of harvested populations and CPUE estimators, catch has traditionally been defined as the number of animals killed. However, Bishir and Lancia (1996) suggested that catch could be defined as sightings and harvests, and they described a joint sightings and harvest CPUE estimator developed in FORTRAN (IBM, Armonk, New York). Lancia et al. (1996) used the CPUE-FORTRAN technique developed by Bishir and Lancia (1996) to estimate the antlered white-tailed deer (*Odocoileus virginianus*) population at Chesapeake Farms, Maryland, from 1981 to 1991. Their approach employed non-linear regression based on iteratively re-weighted least squares, and estimates were validated with a population reconstruction derived from hunter harvest data from Maryland's shotgun season (late November and early December). The 1981-1991 CPUE-FORTRAN estimates were consistently lower than the reconstructed population perhaps because assumptions of equal observability and known changes in the populations were violated to some degree; however, the short duration (1-week) of firearms hunting seasons diminished these effects (Lancia et al. 1996). Nevertheless, CPUE-FORTRAN estimates for the antlered white-tailed deer population revealed trends within the antlered population and were deemed sufficient for many management applications (Lancia et al. 1996, Tilton 2005). Unfortunately, this CPUE estimator was not widely used by biologists, managers, and laypersons possibly due to the cumbersome nature of FORTRAN coding, complicated data input, and slow computation speed.

My objectives were: 1) to make the joint sight/kill CPUE estimator more accessible to potential users by converting the FORTRAN code to JMP scripting language (JSL), 2) to validate the CPUE-JMP technique by comparing 1981-1991 JMP estimates to previous FORTRAN and population reconstruction estimates, 3) to determine the usefulness of the CPUE-JMP estimator for a population under quality deer management (QDM), and 4) to compare the effects of 2-week versus 1-week hunting seasons on the accuracy of the CPUE-JMP estimator.

Study Site

Chesapeake Farms was located on the Eastern Shore of Chesapeake Bay, 10 km southwest of Chestertown, in Kent County, Maryland. Owned by DuPont and operated by DuPont Crop Protection, Chesapeake Farms is a 1,300-ha wildlife management and agricultural research demonstration area. From 1981-1984, regulations allowed 1 antlered male per hunter and starting in 1985, hunters were encouraged to harvest $\geq$1 antlerless deer in addition to an antlered male during Maryland's 1-week shotgun season (Lancia et al. 1996). After the last antlered deer population estimate in 1991, the deer population and management program at Chesapeake Farms changed dramatically (Shaw 2005). In 1993, the 1-week shotgun season was permanently extended to 2-weeks, and in 1994, management shifted to a QDM paradigm with a 7-point restriction placed on all antlered deer harvested. Essentially, QDM seeks to increase the age structure of the male population through hunter restraint and harvest of an appropriate number of females, which results in a more balanced sex ratio and equilibrates the overall population with the available habitat (Miller and Marchinton 1995). Then, in 1997, the harvest restriction was changed to protect antlered males with outside spreads less than 40 cm. Throughout the late 1990s and early 2000s, antlerless harvests increased to reduce crop damage and reach a desirable cultural/biological carrying capacity. Because added harvest pressure was placed on females, the male: female ratio became increasingly balanced from the late 1990s (1:2.8; M.C. Conner, Manager, Chesapeake Farms, unpublished data) to 2006 (1:1.5; M.C. Conner, Manager, Chesapeake Farms, unpublished data) (Rosenberry et al. 2001).

Methods

To generate CPUE estimates, I used daily sightings, harvest, and effort data collected by hunters at Chesapeake Farms (Table 1). All hunters were required to collect these data and annual datasets were compiled by Chesapeake Farms staff.

I converted the original FORTRAN code into JSL using JMP 7 software (SAS Institute, Cary, North Carolina) and compared estimates generated with the CPUE-JMP estimator of the antlered male population at Chesapeake Farms during 1981-1991 vs. CPUE-FORTRAN estimates reported in Lancia et al. (1996). Only harvest data were used to generate CPUE-FORTRAN estimates in 1986 and 1991; hence, for comparison, I generated CPUE-JMP estimates similarly for the same years. Also, I used the CPUE-JMP technique to estimate the antlered population from 1992-2006.

To append the existing (1981-1991) antlered reconstruction, I reconstructed the antlered population at Chesapeake Farms from 1992-2006 with harvest data using the standard reconstruction method (Fry 1949, McCullough 1979, Roseberry and Woolf 1991, Lancia et al. 1996). I validated CPUE-FORTRAN and CPUE-JMP estimates by comparison to reconstructed values (minimum-number-alive estimate) of the antlered white-tailed deer population at Chesapeake Farms (McCullough et al. 1990, Gove et al. 2002). All harvested deer were aged using tooth wear and replacement characteristics (Severinghaus 1949) and comparison to 15 known-age deer jaws from Chesapeake Farms. To make the 1994-2006 CPUE-JMP and reconstructed population comparison equivalent to 1981-1993, I included only males that were vulnerable to harvest (i.e., males whose antlers met the minimum requirement). I used data from hunter harvests in 1991-1993 to estimate the proportion of each male age class that had $\geq$7 points and would be vulnerable to harvest under the 1994-1996 7-point minimum antler restrictions (Table 2) and applied the 1991-1993 derived correction factors to the 1994-1996 antlered population reconstruction. Because pre-existing outside spread data were not available from Chesapeake Farms, I was unable to calculate an outside antler spread correction factor. Therefore, I estimated that 100% of the yearling males and 25% of the 2.5-year-old males would fall short of the 40-cm minimum outside spread restriction (M. C. Conner, Manager, Chesapeake Farms, unpublished data) and applied these proportions to the 1997-2006 reconstruction. From 1997-present, hunters were permitted to harvest mature ($\geq$ 3.5) males regardless of points/spread.

Complete reconstructions lag several years behind harvest data because in some cohorts not all individuals died. Thus, I omitted 2005 and 2006 reconstructed and JMP-CPUE estimates from comparisons (Roseberry and Woolf 1991). Independent-groups *t*-tests for means were used to evaluate all comparisons among JMP-CPUE, FORTRAN-CPUE, and reconstructed values ($\alpha = 0.05$). Due to low sample size and being the only JMP-CPUE estimate to over-estimate reconstructed values, comparisons for 1994 were omitted from analyses.

Results

CPUE-JMP estimates from 1981-1991 were 20% (SE ± 4%) lower than reconstructed population values, but were a 25% improvement over previous CPUE-FORTRAN estimates (27% lower [SE ± 4%]) (Lancia et al. 1996) (Fig. 1). Depending on whether antlered population estimates were generated pre- versus post-antler restrictions and/or during 1-week versus 2-week hunting seasons, on average, 1992-2004 JMP estimates were 21-28% lower than reconstructed antlered population values (Fig. 2). Pre-antler restriction and 1-week hunting season estimates tended to be closer to reconstructed values, though not significantly (Fig. 2). The 1992 CPUE-JMP estimate was based only on harvest data because the 95% confidence interval was unrealistically large (similar to 1986 and 1991) (Lancia et al. 1996). No comparisons between CPUE-JMP, CPUE-FORTRAN, and reconstructed values were statistically significant.

Discussion

The CPUE-JMP estimator is more user-friendly than its FORTRAN predecessor. Previously, users had to manually input harvest, sightings, and effort data into FORTRAN code. In CPUE-JMP, the user chooses to estimate the population based on sight only, harvest only, or sight/harvest data, as discussed in Lancia et al. (1996). Users select appropriate data by clicking on data worksheet column headings and input into the code is automatic. Outputs include the estimate, standard error, 95% confidence limits, fitted line graph, and correlation matrix, which allow the user to determine appropriateness of data fit (Fig. 3). Intuitive interfacing and text/graphic results available through JMP 7 enhance ease of use, visualization of the data and outputs, flexibility of analysis options, and computation speed. The CPUE-JMP estimator is available to the public at the online JMP user community file exchange (http://www.jmp.com/community/).

From 1981-1991, the CPUE-JMP estimates were closer to the reconstructed values than were the previous CPUE-FORTRAN estimates because JMP uses more sophisticated algorithms and has stricter convergence criteria than the CPUE-FORTRAN program (C. Barker, Research Statistician, SAS Institute, personal communication). Also, starting values [population size (*N*), probability that a sighting results in a harvest (*p*), and number of animals sighted per animal in the population per effort (*b*)] were computed differently in the CPUE-JMP estimator. The JSL places minimum and maximum restrictions on the starting values, which likely improves errant estimates (Bishir and Lancia 1996). In JSL, starting values were calculated from the input data, but users may enter their own initial values if desired. I used default starting values to generate all CPUE-JMP estimates.

When applied to QDM populations, the CPUE-JMP estimator performed at essentially the same level as it had pre-QDM. However, using a CPUE technique in a QDM setting could introduce some confounding factors and reduce year-to-year consistency of estimates. First, an increase in older age class males increases the likelihood of heterogeneous observability – the single biggest factor in the negative bias of CPUE estimates (White et al. 1982, Lancia et al. 1996). Following antler restrictions, male age structure and harvest shifted from younger males (mostly 1.5-year-old males) to predominantly 2.5- and 3.5-year-old and older males (Shaw 2005) (Fig. 4). At Chesapeake Farms, previous studies have shown that a heterogeneity mark-recapture model best matched observations of marked deer, and heterogeneous observability was detected in radiocollared does (Conner 1986, Lancia et al. 1995). Yearling males display higher observability than older age class males (McCullough 1979), and observability decreased as the population moved to an older age structure (Roseberry and Klimstra 1974).

Second, hunter selectivity often increases beyond the required antlered restriction and could introduce an additional source of heterogeneity (Roseberry and Klimstra 1974, Coe et al. 1980, Novak et al. 1991). At Chesapeake Farms, hunting was conducted from the same permanent stands year after year, so sampling was spatially consistent removing a potential bias. As expected, the CPUE estimator performed better when a larger proportion of the population was removed (Gould and Pollock 1997). The CPUE-JMP estimator revealed general upward and downward trends in the population (Fig. 5), such as the drop in harvestable antlered males immediately following the implementation of antler restrictions and subsequent rise in harvestable animals as younger males were allowed to reach older age classes. Although trends are accurately depicted by the technique, estimates of individual-year populations should be viewed with caution. The estimator performed well over a variety of herd management paradigms and consistently produced estimates sufficient for most deer management needs.

Increasing the hunting season to 2-weeks increased the difference between CPUE-JMP and reconstructed population estimates. Longer hunting seasons increase the heterogeneity of animal observability and occurrence of unknown changes within the population (Lancia et al. 1996). Novak et al. (1991) stated that increasing the number of sampling periods for CPUE techniques generally improved the accuracy of estimates. However, the 2-week hunting season estimates deviated further from reconstructed values than 1-week hunting season estimates because total removal did not increase proportionally to the amount of time available to hunt (Table 3). Too few antlered deer were harvested on most individual days during hunting season and the linear relationship between catch and effort weakened. Also, with the longer 2-week season, deer are more likely to be affected by hunting pressure, exhibit greater individual heterogeneity in sighting probability, and become less observable as the season progresses (Roseberry and Klimstra 1974).

Conclusion

CPUE estimation is appropriate for large ungulates primarily because these populations are intensively-harvested, and their habitats are complex and prohibit direct census counts (Novak et al. 1991). This technique is most applicable to closely controlled hunts where hunters collect accurate catch and effort data, often at little or no cost to the management agencies, which are used in the estimators. Users should be reminded that if there are antler restrictions on male harvest, then sightings data must be adjusted to include only harvest-eligible males. The CPUE-JMP estimator generated estimates that were lower than reconstructed values but reflected trends under traditional white-tailed deer and QDM management regimes and harvest strategies. However, biologists should be careful because sustainable harvest recommendations based on low population estimates would themselves typically be biased low, and estimates gauging the success of population reduction programs would likely be overly optimistic (Lancia et al. 1996).

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Table 1. An example of data collected by hunters during Maryland's 1-week shotgun season for white-tailed deer, Chesapeake Farms, Maryland, 1988.

Day	1	2	3	4	5	6	7
Hunters	39	25	31	27	17	41	46
Hours hunted	249	114.75	85.52	165.5	68	246.75	298.25
Bucks killed	11	2	1	1	0	9	4
Bucks seen	30	5	15	13	12	23	19

Table 2. Percent of each antlered male age class that met $\geq$7 points harvest restriction, Chesapeake Farms, Maryland, 1994-1996.

Antlered male age class	Percent (%) eligible antlered males for harvest under point restriction
1.5	21%
2.5	44%
3.5	68%
4.5 and older	100%

Table 3. Overall antlered male harvest during 1-week and 2-week long shotgun seasons, Chesapeake Farms, Maryland, 1981-2004.

Year	Antlered harvest	Year	Antlered harvest
1-week shotgun season		2-week shotgun season	
1981	19	1993	25
1982	23	1994	19
1983	34	1995	11
1984	28	1996	12
1985	26	1997	11
1986	21	1998	22
1987	32	1999	19
1988	28	2000	26
1989	39	2001	18
1990	33	2002	20
1991	34	2003	15
1992	35	2004	16

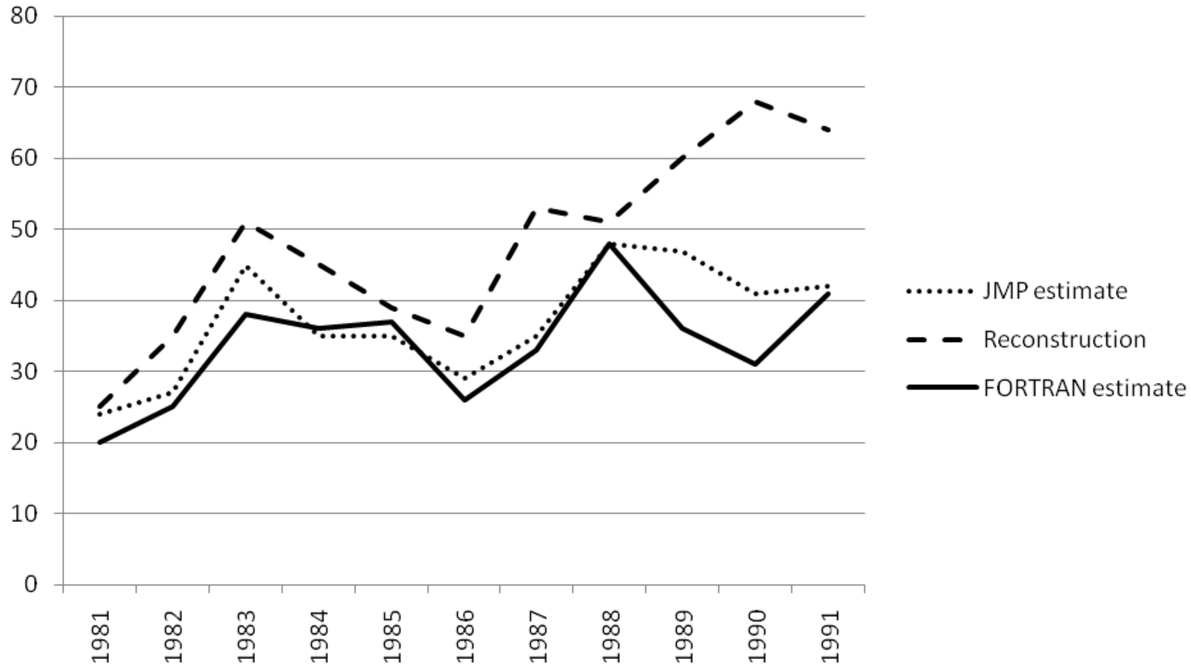

Figure 1. Comparison of CPUE-JMP, reconstructed, and FORTRAN estimates for the antlered male white-tailed deer population at Chesapeake Farms, Maryland, 1981-1991. CPUE-JMP and FORTRAN estimates from 1986 and 1991 are based on harvest data only.

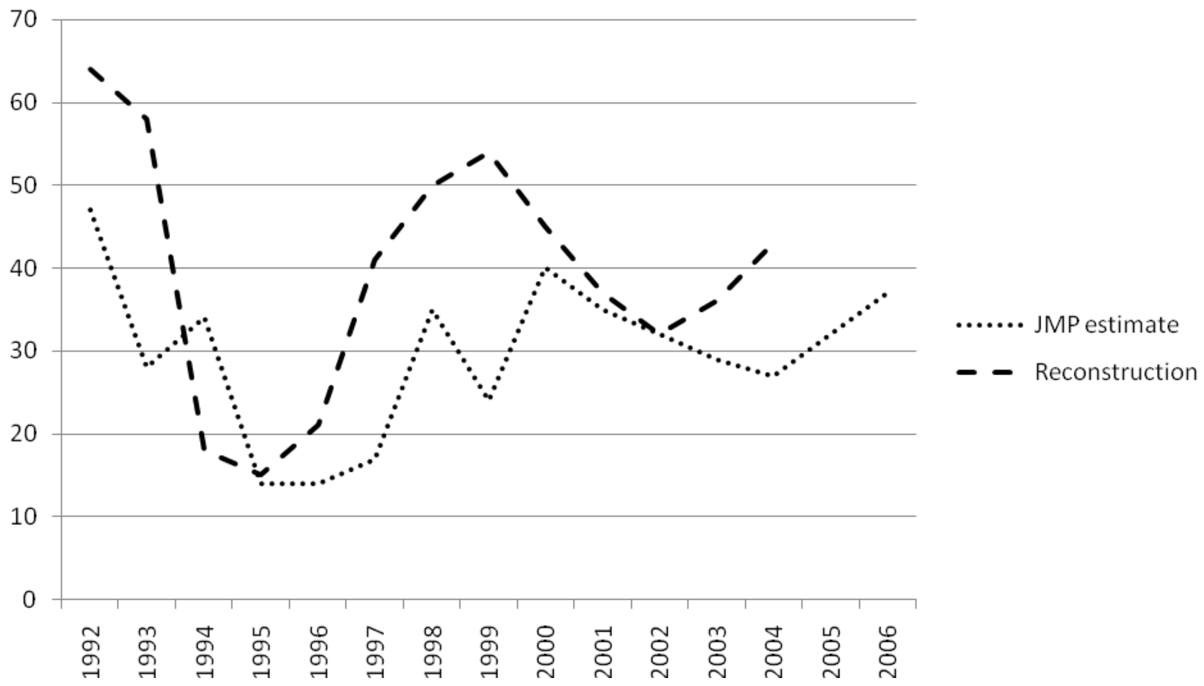

Figure 2. Comparison of the CPUE-JMP and reconstructed estimates for the antlered male white-tailed deer population at Chesapeake Farms, Maryland, 1992-2006. The incomplete 2005 and 2006 reconstructed estimates are omitted. The 1992 CPUE-JMP estimate was based on harvest data only.

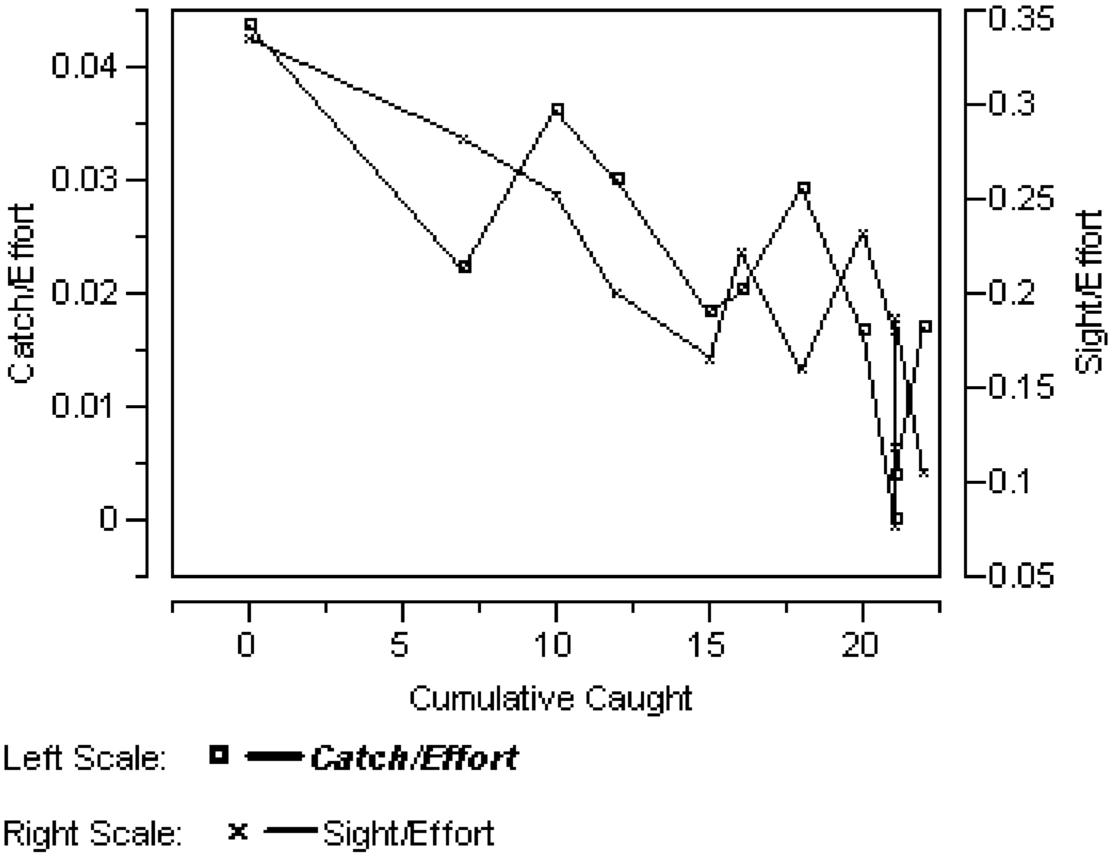

Figure 3. Overlay plot generated by CPUE-JMP scripting language indicating goodness of fit for catch/effort (number of animals killed per unit effort) and sight/effort (number of animals sighted per unit effort) data. A fitted line for data must exhibit negative slope to result in an estimate (x-intercept). Output was generated from Chesapeake Farms antlered male white-tailed deer data, 2000.

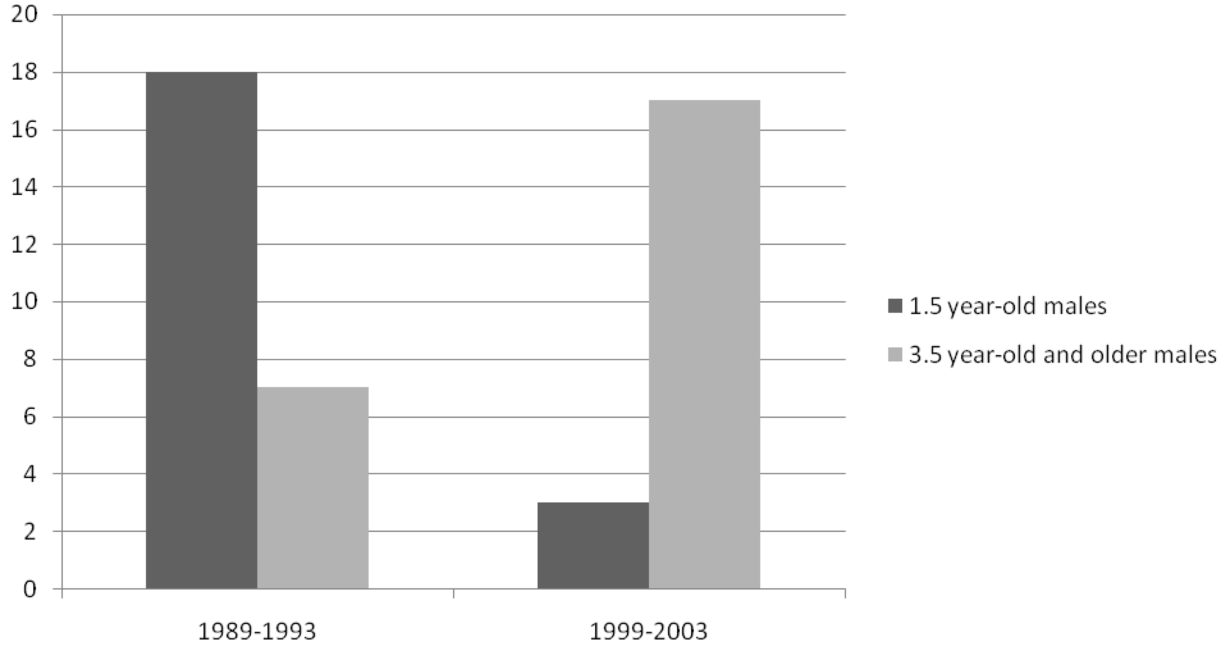

Figure 4. Average antlered male harvest, Chesapeake Farms, Maryland, 1989-1993 and 1999-2003.

Figure 5. Comparison of CPUE-JMP and reconstructed estimates for the antlered male white-tailed deer population at Chesapeake Farms, Maryland, 1981-2006. Hunting season length changed from 1-week to 2-weeks in 1993, and antler restrictions began in 1994.

INTRACRANIAL ABSCESSATION AS A NATURAL MORTALITY FACTOR FOR ADULT MALE WHITE-TAILED DEER (*ODOCOILEUS* VIRGINIANUS) IN KENT COUNTY, MARYLAND

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ABSTRACT: Intracranial abscessation is a cause of natural mortality among free-ranging white-tailed deer (*Odocoileus virginianus*) across portions of the United States and Canada. Intracranial abscesses caused by *Arcanobacterium pyogenes* disproportionately affect adult male white-tailed deer. From 2003-2008, we evaluated the occurrence of intracranial abscessation among adult (≥ 2.5 years) radiocollared male white-tailed deer (n=33) at a large private property in Kent County, Maryland. We documented mortality and necropsied 26 of the 33 deer. In 2007, we collected swabs from the antler bases and nasopharyngeal membranes of additional living male white-tailed deer in Maryland (n=9) and Texas (n=10) and from freshly rubbed (n=7) and un-rubbed (n=7) trees in Maryland. Swabs were cultured for the presence/absence of *A. pyogenes*. In Maryland, nine (35%) of the 26 necropsied radiocollared males had intracranial abscesses. Five (56%) of nine Maryland males and none (0%) of 10 Texas males cultured positive for *A. pyogenes*. No rubbed or un-rubbed trees at the Maryland site cultured positive for *A. pyogenes*. The rate of intracranial abscess among adult male white-tailed deer at the Maryland site (35%) exceeds reported rates for other regions of the United States (9%).

KEYWORDS: *Arcanobacterium pyogenes*, intracranial abscessation, Maryland, *Odocoileus virginianus*, Texas, white-tailed deer.

Intracranial abscessation is a documented source of natural mortality in white-tailed deer (*Odocoileus virginianus*) across portions of the United States and Canada (Baumann et al., 2001). Occurring primarily between October and April, cases of intracranial abscess are thought to be directly related to breeding activities (i.e., antler sparring, rubbing behavior, or antler casting) and disproportionately affect male white-tailed deer (Davidson et al., 1990). *Arcanobacterium pyogenes* (formerly *Actinomyces*) and/or other bacteria enter via subcutaneous cuts, abrasions, or injured pedicles and penetration of the cranium is thought to occur primarily through the suture between the parietal and frontal bones (Davidson et al., 1990). Associated symptoms of abscesses include incoordination, fearlessness, weakness, blindness, emaciation and potentially death (Davidson et al., 1990).

Beginning in mid-October, male white-tailed deer vigorously rub tree saplings with their antlers and foreheads (Atkeson and Marchinton, 1982). Antler rubbing polishes the antlers, creates scent posts, and functions in breeding behavior (Kile and Marchinton, 1977). It is possible that *A. pyogenes* may be transmitted between males using common trees for antler rubbing, however research is lacking. Intracranial abscessation can afflict deer regardless of sex or age (Davidson et al., 1990; Nettles et al., 2002; Chirino-Trejo et al., 2003). In a survey of deer mortality reports from the Southeastern Cooperative Wildlife Disease Study and other state (Colorado, Florida, Idaho, Michigan, Mississippi, Missouri, New Jersey, New York, Oklahoma, Texas, Washington, Wisconsin, Wyoming) and provincial (Alberta, Ontario, Saskatchewan) agencies, intracranial abscessation accounted for 2.2% of sex nonspecific deer natural mortality, 4.9% of male natural mortality, and 9.3% of adult ($\geq$ 2.5) male natural mortality (Baumann et al., 2001). Intracranial abscessation is considered extremely rare in Texas and southern portions of Oklahoma, and it is believed the region's arid climate might discourage survival of the infective organisms (Baumann et al., 2001).

Our objectives were to determine the rate of intracranial abscess as a source of natural mortality among adult male white-tailed deer ($\geq$ 2.5), evaluate the prevalence of *A. pyogenes* in the bacterial flora of adult male white-tailed deer in arid (south Texas) and more verdant (Maryland) habitats, and examine the possible role of antler rub trees in the transmission of *A. pyogenes* between male deer.

Our Maryland site was a 1,300-ha wildlife management and agricultural research demonstration area in Kent County, Maryland (N 39°10', W 76°10') located on the Eastern Shore of Chesapeake Bay, 10 km southwest of Chestertown. The site was privately-owned and 50% of the study area was forested with non-alluvial swamps consisting primarily of oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), and red maple (*Acer rubrum*). Greenbriar (*Smilax* spp.), sweet pepperbush (*Clethra alnifolia*), and highbush blueberry (*Vaccinium corymbosum*) dominated the understory. Cash crops, field corn (*Zea mays*) and soybeans (*Glycine max*) composed 20% of the study area. Fallow fields composed 13% of the farm [orchard grass (*Dactylis glomerata*), clover (*Trifolium* spp.), sorghum (*Sorghum* spp.), and rye (*Lolium multiflorum*)]. The remaining 17% was composed of

non-forested wildlife cover and man-made waterfowl impoundments (Shaw, 2005). Recently, deer density was estimated at 1 deer/3 ha (Shaw, 2005).

Our Texas site centered on two pastures within a 103,691-ha commercial cattle operation located in the eastern Rio Grande Plains region, 4 km east of Kingsville in Kleberg County, Texas, (N 27°31', W 97°55'). There were no high fences and the mixed-shrub rangeland was dominated by mesquite (*Prosopis glandulosa*) and huisache (*Acacia farnesiana*) (McCoy et al., 2005). The pastures were stocked with domestic cattle at an average rate of 1 animal unit/10 ha and deer density was estimated at 1 deer/17 ha (McCoy et al., 2005).

From 2003-2008 at our Maryland site, we monitored 33 adult ($\geq$ 2.5 years old) male white-tailed deer with GPS radiocollars (Tomberlin, 2007). The radiocollars were equipped with mortality sensors that activated within eight hours of death, and deer were retrieved 12 to 48 hours post-mortem. Field necropsies were performed on-site. Brain cases were opened to determine presence of intracranial abscess. Using a CO_2- powered dart projector with 2.4 ml Telazol (200 mg/ml) and 0.6 ml Xylazine (450 mg/ml) drug combination, nine deer were captured to fit with radiocollars from 20 June – 30 July 2007 (Fort Dodge Animal Health, 800 Fifth Street, Fort Dodge, IA 50501; Wildlife Laboratories, Inc., 1401 Duff Drive, Suite 600, Fort Collins, CO, 80524). From these deer, nasopharyngeal membranes and antler bases were independently swabbed until thoroughly covered with epithelial residue using Remel Bacti-Swab transport swabs (Remel Products, 12076 Santa Fe Drive, Lenexa, KS 66215). Deer were examined for injuries, large tick loads, abrasions, or cuts. At the Texas site, nasopharyngeal and antler base swabs were taken from 10 adult ($\geq$ 2.5 years old) male white-tailed deer captured by helicopter net-gunning during a GPS-collar study on 30 October 2007. Deer sampled from both study areas were estimated to be approximately the same age based on morphological characteristics. Tree rub samples were collected on 23 October 2007 from seven freshly-rubbed (approximately $\leq$ 24 hours) trees at the Maryland site. The collection date was centered within the period of the white-tailed deer breeding season when antler rubbing and scraping peaked (Kile and Marchinton, 1977). We selected the most-freshly rubbed tree that we could locate, irrespective of tree species, in an hour-long search within seven unique land covers that are representative of the study area and more widely distributed across the overall landscape. Tree species was recorded and the closest un-rubbed tree of the same species was swabbed and cultured as a control. Antler, nasopharyngeal, and tree swabs were refrigerated for up to 24 hours before delivery to the Centreville Animal Health Diagnostic Lab (Centreville, Maryland) where samples were plated on blood agar. A gram stain and catalase test was conducted for each sample. All aerobic gram (-) and (+) bacteria were identified to genus and speciated on the basis of morphology, staining characteristics, and biochemical utilization using standard ASM techniques (Lennette et al., 1985; Holt et al., 1994). All procedures for research followed the guidelines for the Institutional Animal Care and Use Committee at North Carolina State University (Approval Number 05-024-0).

Of the 33 Maryland radiocollared deer, we documented mortality for 26 individuals (Figure 1). Cause of death was not determined for five (19%) of the 26 necropsied deer. Nine (35%) of the 26 known-fate deer had intracranial abscesses (Figure 1). Each affected male had exudate visible by external examination of at least one antler pedicle or orbit and had one or more abscesses inside the cranial cavity (Figure 2). Eight (89%) of the nine deer with intracranial abscesses were older-age class ($\geq$ 4.5) males, representing over half (62%) of the older age-class males in our sample (Figure 1). Cultures from the nasopharyngeal and antler base samples of 56% (n=5) of the Maryland deer were positive for *A. pyogenes*. Other bacteria identified included *Staphylococcus* (n=6), *Bacillus* (n=4), *Klebsiella* (n=1), and *Pseudomonas* (n=1) (Davidson et al., 1990; Baumann et al., 2001). Eighty percent (n=4) of the *A. pyogenes* results came from the nasopharyngeal samples. None of the Texas deer cultured positive for *A. pyogenes*. Other bacteria identified from Texas samples included *Staphylococcus* (n=8) and *Bacillus* (n=9). The failure to culture *A. pyogenes* from nasopharyngeal or antler base swabs suggests that presence of this organism associated with intracranial abscessation may be limited at our Texas site. It is possible the arid climate may discourage growth of *A. pyogenes,* however our study design does not specifically address this question.

A. pyogenes or other bacteria were not detected from the freshly rubbed or un-rubbed trees in Maryland. Species sampled included loblolly pine (*Pinus taeda*) (n=2), black gum (n=4), sweet gum (n=2), white oak (*Quercus alba*) (n=2), black cherry (*Prunus serotina*) (n=2), and black locust (*Robinia pseudoacacia*) (n=2). Failure to culture bacteria from the trees suggests that our culture methods were not optimized for bacterial cultures of tree bark. If a rubbed tree was contaminated with *A. pyogenes*, it is also possible the tree's non-specific immune defenses including pathogen-resistant proteins would kill or retard the growth of *A. pyogenes* (Jones and Dangl, 2006).

During this study, *A. pyogenes* was common in the nasopharyngeal mucosa of male deer and we believe that direct contact between competing males could conceivably be a more significant mode of bacterial transmission than using common trees for antler rubbing. Further, during breeding behavior (antler sparring) and social grooming, there is the possibility of transfer of contaminated mucus between individuals (Forand and Marchinton, 1989). The intracranial abscess prevalence for radiocollared males in Maryland is conservative because we did not examine five unknown mortalities for the presence of diffuse suppurative meningoencephalitis (Figure 1) and because of the limitations of the field necropsy techniques used (Davidson et al., 1990). Histologic evaluation of brain and meninges might have identified additional cases (Davidson et al., 1990). Because of management for increased male age structure as part of a quality deer management [QDM] paradigm at the Maryland site, intrasexual competition may be elevated during the breeding season, which would be expected to predispose individuals to disproportionately more injuries than would occur in less intensively managed populations. High deer density at the Maryland site also could be a factor increasing stress and injuries during breeding season, thus propagating the occurrence of intracranial abscessation. If intracranial abscesses are additive to natural and harvest mortality in QDM-managed populations, it could be a significant impediment to successful QDM and should be considered by managers, wildlife agencies, and hunters on the Delmarva Peninsula.

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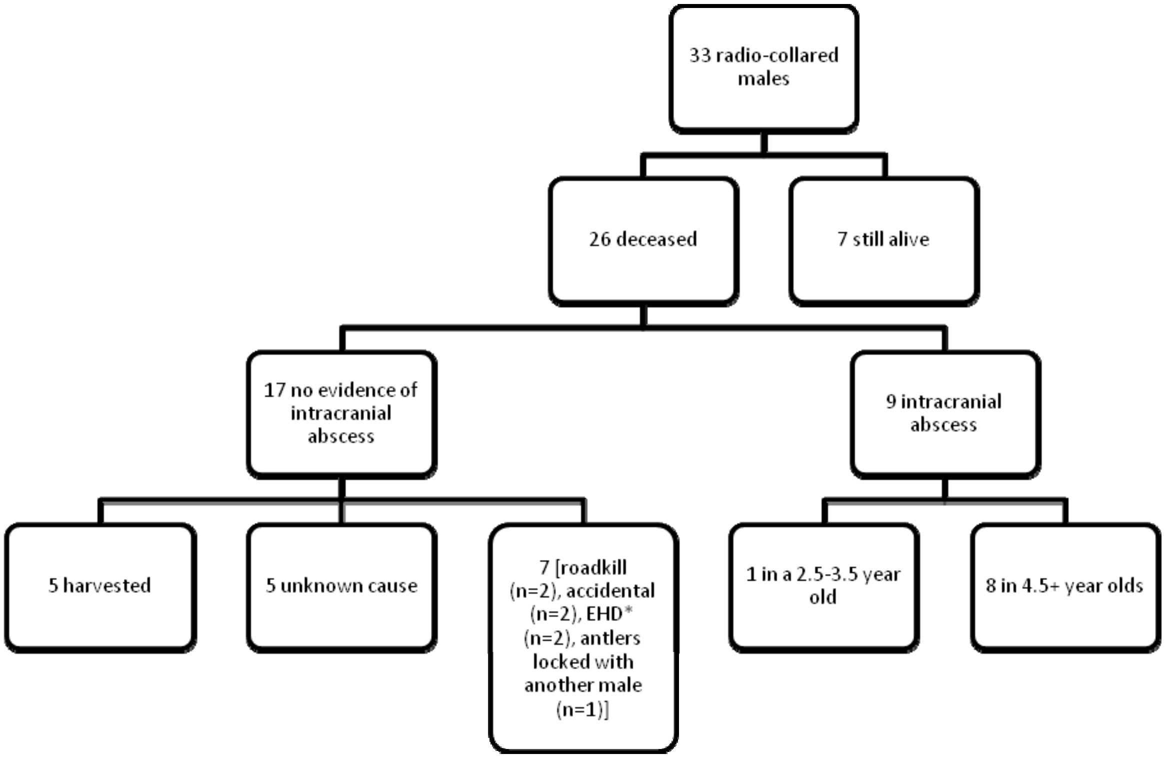

Figure 1. The fate of 33 adult male radiocollared white-tailed deer captured at Chesapeake Farms, Maryland, 2003-2007. *EHD – Epizootic Hemorrhagic Disease

Figure 2. Exudate on the antler pedicle of 4.5-year old male white-tailed deer at Chesapeake Farms, Maryland, 2006. Note the skull fragment that split away from the antler pedicle. Photo courtesy of M. Conner.

MANAGEMENT IMPLICATIONS

During Maryland's 2-week firearms season, low hunting pressure (compared to neighboring properties) has enabled Chesapeake Farms to serve as a pseudo-refuge in context of the larger landscape (Chapter 1). It is evident that current levels of hunting pressure do not drastically alter adult male behavior. If current hunting pressure levels are maintained, the refuge effect of Chesapeake Farms might allow more juvenile and young adult males to increase annual survival rates because of harvest restrictions and shift the age structure of the antlered male population toward older age classes at Chesapeake Farms and neighboring properties. Also, current methods and routes used to transport hunters to stand locations result in short-distance, temporary flight responses by adult male white-tailed deer and do not jeopardize the potential success of subsequent hunters. By examining micro-scale deer movement in relation to known hunter locations and assuming that radiocollared deer were a representative sample of the overall male population, I noted several hunting stands that could be moved from their current position to increase hunter harvest opportunity. To intercept more deer movement, hunting stand F1 should be moved 75 meters west, and hunting stand R2 should be moved 100 meters southwest. Although hunting within the 2 delineated refuges might be successful, I recommend that they be kept no-hunting zones to provide sanctuary during the firearms hunting season for white-tailed deer.

Adult male white-tailed deer excursions are primarily driven by breeding season-related motives, and movements outside normal home ranges might expedite gene flow between white-tailed deer herds, but could also potentially increase the rate of disease transmission. Linked to the abundant security and escape cover and relatively low hunting pressure exerted on Chesapeake Farms, hunting is an unlikely instigating reason for adult male excursions (Chapter 2). If current habitat management (e.g., logging to maintain wooded, early successional habitat; wildlife cover plantings) and low hunting pressures are maintained, hunting should not prompt excursions and subject older age class males to higher rates of vulnerability than normal. However, changes in hunting strategy (e.g., hunters pushing deer to one another instead of stand hunting) would likely cause excursions to occur more frequently during hunting season. By saturating a lower density white-tailed deer population with GPS collars, researchers might be able to assign more definitive motives to excursions such as males searching for estrous females, males following receptive females back to her core area, and female incitation of male-male competition.

Interestingly, in my study, about 20% of adult males made excursions during hunting season which would violate the closed population assumption of the catch-per-unit-effort technique. However, because excursions are a temporary phenomenon, their effect on estimates would be minimal at worst. To minimize violation of equal catchability assumptions, hunters should be encouraged to harvest the first legal antlered and antlerless white-tailed deer that is encountered. Also, managers should strive to evenly distribute hunting pressure across Chesapeake Farms both spatially and temporally to reduce potential biases caused by under- and over-sampling different portions of the property. Overall, the JMP-CPUE estimator is an excellent technique for producing population estimates on intensively-managed properties where hunters are confined to fixed hunting stands and required to engage in rigorous data collection (Chapter 3). The method is sufficient for evaluating long-term trends related to management goals and objectives, but other techniques are probably more appropriate for single-season estimates (e.g., camera surveys, spotlight counts).

Lastly, intracranial abscessation is a significant natural mortality factor for adult male white-tailed deer in Maryland, especially ≥ 4.5-year-olds (Chapter 4). Because antlered males 4.5-years-old and older are at such risk of intracranial abscessation (62%), hunters should be educated to harvest older age class adult males even if deer do not meet minimum antler spread restrictions. Unfortunately, it is difficult to ascertain why Chesapeake Farms (and other areas on the Delmarva Peninsula) have disproportionately higher rates of intracranial abscessation than other regions of the United States. Whether this impact is related to climate, disproportionately high rates of intrasexual competition, or other reasons remains unknown. Although my research did not examine the correlation between antler characteristics and the occurrence of intracranial abscessation, anecdotal evidence suggests that males with asymmetrical, abnormal points near one or both pedicles are at higher risk of intracranial abscessation. Non-typical antler growth is partially contributable to previous trauma caused by sparring, irregular antler casting, or otherwise damaging the pedicle, thus predisposing the deer to increased risk of developing an abscess. If future research indicates a strong positive relationship between abnormal antler growth and intracranial abscessation, adult males possessing irregular antler characteristics near the pedicle could be selectively harvested by hunters to lessen the impact of this natural mortality factor. Unfortunately, in Maryland, this may be difficult due to firearms season (first 2 weeks of December) occurring after the peak of intracranial abscessation mortality (October and November) at Chesapeake Farms. Regardless, managers at Chesapeake Farms should be aware that intracranial abscessation presents a major obstacle to quality deer management objectives.