An assessment of Quality Deer Management on a private hunt club in the Virginia Piedmont

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ABSTRACT
I examined the efficacy of Quality Deer Management (QDM) on Amelia Springs hunt club in Amelia County, Virginia, during 2003-2006. I examined home range dynamics of male white-tailed deer (*Odocoileus virginianus*), deer/hunter interactions, and aspects of population dynamics. I also developed a new rocket net method to capture deer using a remote video system that was more efficient than traditional methods. I monitored 20 deer; 50% died due to hunting and 15% to natural mortality. The emigration rate for juvenile males was 46%, dispersal distance averaged 6.4 km. I used Home Range Extension (HRE) in ArcView to generate annual home ranges (adaptive-kernel) for 16 male deer; I also generated annual and seasonal home ranges using MCP. Annual and seasonal home ranges (MCP) of adult males were larger than those of juveniles. Adult male annual home ranges averaged 2.5 km$^2$ and juveniles 0.9 km$^2$. Seasonal home ranges of adult males were 1.6 km$^2$ and 1.3 km$^2$ during non-hunting and hunting seasons respectively. Juvenile non-hunting and hunting season home ranges were 0.6 km$^2$ and 0.8 km$^2$ respectively. I detected no differences in day/night movements of male deer during the hunting season; however, deer appeared to avoid areas that were hunted based on hunter GPS locations and deer locations during the hunting season. Frequency of deer movement increased during October-November. Population estimates based on remote camera mark-recapture averaged 60 antlered males for the 3-year survey period. Using population reconstruction, the minimum buck:doe ratio was 1:1.8. Estimated density of antlered males was 4.1/km$^2$, in Amelia County, and 5.0/km$^2$ for Amelia Springs. Deer harvested on Amelia Springs, compared to deer harvested on other hunt clubs in Amelia County, were larger. Antler diameters averaged 32.6mm on Amelia Springs versus 26.9mm for other Amelia county hunt clubs, average age at harvest for 2+ males was higher on Amelia Springs (2.4) than other Amelia county hunt clubs (2.2), and dressed body weights averaged 11.2kg heavier (46.2 kg versus 35 kg) on Amelia Springs. QDM on Amelia Springs appears to be successful based on the results. While bigger bucks existed on Amelia Springs, hunters failed to encounter them. Hunters likely would increase buck sightings during the hunting season by becoming more mobile. Expectations of the size of animal (antlers) Amelia Springs can produce should be adjusted to reflect what is possible based on the habitat. The harvest program in place should be continued at the current level for continued success using QDM.
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INTRODUCTION

White-tailed deer (Odocoileus virginianus) populations are managed intensively throughout the United States to attain specific harvest and population goals (Lancia et al. 1988, Waller and Alverson 1997, Brown et al. 2000). The primary management strategy used to control deer populations is regulated hunting (Brown et al. 2000). Traditionally, most management strategies in the southeastern United States were designed to maximize harvest rates and hunter satisfaction while maintaining populations below carrying capacity (Newsom 1984). Under this traditional approach to harvest, deer were harvested with little regard for the quality of deer (i.e. antler size). Today, hunters are better informed about alternative management options and thus, seek higher quality deer hunting opportunities (Ditchkoff et al. 1997). As a result, quality deer management (QDM) is an increasingly popular management tool used throughout the range of the white-tailed deer. QDM is the voluntary use of restraint in the harvest of young bucks combined with an appropriate antlerless deer harvest to maintain a healthy deer population in balance with the habitat (Hamilton et al. 1995). The definitions of quality deer varies across geographic region, but are generally deer that are larger in antler size (males) and body mass (both sexes). Increasing the age structure (larger proportion of older males), restoring a more balanced sex ratio (reduction in females), and emphasizing hunters as managers distinguishes QDM from traditional management techniques (Miller and Marchintosh 1995). Although white-tailed deer are arguably the most extensively studied animal in the United States, very little literature exists on the effectiveness of QDM.
The Virginia Deer Hunters Association, (VDHA), a volunteer, statewide, non-profit organization, was founded in 1985 and is dedicated to responsible management of whitetail deer as a valuable resource. An Amelia County hunt club, managed by VDHA members, has practiced QDM with mixed results since 1992. As a result, the VDHA wished to determine if QDM was effective on the hunt club. In conjunction with the Virginia Department of Game and Inland Fisheries (VDGIF), the VDHA approached Virginia Polytechnic and State University (VPI & SU) to conduct a study to assess QDM. The goal of this project was to evaluate the effectiveness of Quality Deer Management on the Amelia Springs hunt club study area (Figure 1).

This thesis evaluates Quality Deer Management using male home range data, population estimates, and population morphological measurements from harvest data from Amelia County (1992-2005). Chapter 1 describes a new technique developed cooperatively with VDGIF and First Witness Video (Mt. Sydney, VA.) to more efficiently capture deer using a rocket net and a remote video system. Chapter 2 defines seasonal home range size and movement attributes of male deer on Amelia Springs hunt club. Chapter 3 quantifies deer densities on Amelia Springs hunt club, and Chapter 4 provides comparisons of harvest information from other Amelia County hunt clubs to the study site.

OBJECTIVES AND HYPOTHESES

The goal of this research was to determine the effectiveness of QDM on Amelia Spring hunt club. To accomplish that goal, my specific objectives were to:

1. Determine the seasonal home range size and movements of adult male white-tailed deer in relation to hunting pressure on Amelia Springs hunt club.
• Ho: Home ranges and movements of male white-tailed deer on Amelia Springs hunt club did not differ between hunting and non-hunting seasons.

2. Determine deer densities on the Amelia Springs hunt club for comparison to Amelia county-wide densities.

• Ho: Deer densities on Amelia Springs hunt club and within Amelia County do not differ.

3. Compare Amelia Springs hunt club deer harvest information (e.g. morphology: weight, antler size.) to other Deer Management Assistance Program (DMAP) managed hunt clubs in Amelia County.

• Ho: There is no difference in morphological measures of deer quality (e.g., weight, antler size) for deer harvested on Amelia Spring hunt club compared to other DMAP managed hunt clubs in Amelia County.

GENERAL METHODS

Description of Study Area

Amelia Springs Hunt Club is a 1,538 ha property (Figure 1) located 3.2 km north of Jetersville, Virginia. The land, which is owned by John Hancock Insurance Company, F&P Enterprises, and Ben Underwood, is an area traditionally used for recreational sport hunting. The Amelia Springs Hunt club leased the property in 1992 and has practiced QDM since its inception. The club has an aggressive doe harvest program and had a minimum buck harvest standard of 40.64cm of main antler beam until 2004, when it was increased to 45.72cm. They have participated in the Deer Management Assistance Program (DMAP) since 1992. The study area is in the Piedmont Province, a non-mountainous region incised by southeast-trending river valleys and characterized by gently rolling topography (Orme 2002). Elevation ranged from 76 to 122 meters. Average temperatures (1971-2000) range from a maximum of 20.2°C to a low of 6.4°C with an overall mean temperature of 13.3°C. Average yearly precipitation (1971-2000) was 114
cm (Southeast Regional Climate Center 2004). The site is surrounded on all sides by private lands of various habitats, including agriculture, hardwood forest, mixed-hardwood forest, and home sites.

Due to heavy settlement in the nineteenth century and subsequent cultivation, the Piedmont is characterized by a patchwork of second growth forest communities of various ages and composition (Braun 1950). Few areas of old growth forest remain in this region. The region supports hardwoods and mixed hardwood forest communities. Pine (Pinus sp.) dominated communities occur on dry upper slopes and ridge tops, sites generally less favorable for hardwoods. Also, pines rapidly colonize disturbed sites (Orme 2002). Many sites that potentially can support hardwood stands now are occupied by pines (Oosting 1942) and 75% of the study area was managed intensively for loblolly pine (P. taeda) in various stages of re-growth. Oak (Quercus sp.) is the dominant hardwood species. Drier sites support post oak (Q. stellata), chestnut oak (Q. prinus) and scarlet oak (Q. coccinea). In addition to oaks, xeric upland sites are occupied by mockernut hickory (Carya tomentosa) and pignut hickory (C. glabra). The mesic uplands dominant tree species include white oak (Q. alba), northern red oak (Q. rubra) and black oak (Q. veluntina). Non-oak species found here include tulip poplar (Liriodendron tulipefera), American beech (Fagus grandifolia), sugar maple (Acer saccharum), and hemlock (Tsuga canadensis). Bottomland forest communities found along narrow stream valleys support river birch (Betula nigra), cottonwood (Populus deltoids), and sycamore (Platanus occidentalis), which occur on areas subject to frequent flooding. Other common bottomland species include, willow oak (Q. phellos), water oak (Q. nigra) and sugarberry (Celtis laevigata) (Orme 2002). Additionally, a small fraction of the area
(0.5%) was planted in food plots for wildlife; common plantings include red clover
(*Trifolium pratense*), buck oats (*Avena sp.*), and corn (*Zea mays*).

**Trapping and Handling**

Trapping, handling, and monitoring procedures were established in January 2004
and approved by the animal care committee at VPI and SU (04-028-F&W). Our goal was
to trap and mark a minimum of 20 male deer (available transmitters) and as many
females as could be captured. We trapped deer during January-September 2004-05,
excluding the April-May turkey hunting season, using rocket nets (Hawkins et al. 1968).
We also attempted to capture deer using drops nets (Ramsey 1968) and clover traps
(Clover 1956), but with no success. We physically restrained captured deer for data
collection. During May-September, when growing antlers were fragile, we used telemetry
darts (Lovett and Hill 1977) to capture deer. This method was used to minimize damage
to antlers of mature bucks. Deer were immobilized with a 2:1 mixture of tiletamine and
zolazepam hydrochloride (Telazol®, Fort Dodge Animal Health, Fort Dodge, Iowa,
USA) with xylazine hydrochloride (300mg/ml) at a dosage of 1 cc/22.7 kg (50 lbs.).
While deer were immobilized, we classified each animal as juvenile or adult based on
relative body size and length of head, took morphological measurements of males, and
recorded sex (Appendix B). We measured chest girth at the shoulder to estimate weight.
All deer were marked in each ear with ear tags (National Band and Tag, Newport,
Kentucky, USA) color coded by sex and numbered for individual identification. The
 corresponding number was tattooed inside the right ear. Each adult male was fitted with
an ear tag transmitter (Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA) in the
right ear. Morphological measurements taken included: number of antler points, length of
main beams (cm), circumference of both antler bases (cm) one inch above the burr, and greatest inside spread (cm).

Telemetry

We monitored radio tagged deer by ground surveys to determine location and activity status (radio signal on active or mortality mode). Deer locations were determined by triangulations consisting of a minimum of 3 bearings taken from known telemetry stations along roads within a 30-minute time interval. We used software program Locate 3 (Nams 2006) to calculate locations and Global Positioning System (GPS) to determine the location of the telemetry stations. Each bearing was rated based on signal strength and confidence factor on a scale of 1-5 (Appendix C). We tested telemetry error by placing 5 radio tags at known UTM coordinates on the study site and obtaining bearings from 3 stations to determine bearing error, or how many degrees our readings were off from the true bearing. Telemetry error was 6.3°. Transmitter range was ±1.6 km.

During the non-hunting season, I located each radio-marked deer at randomly selected times 2 or 3 times/week. To determine location times, I divided the week into 42 4-hr blocks (7 days x 6 4-hr blocks /day) and assigned a number to each block. Number 1 was the first 4-hr block on day 1 and number 42 was the last 4-hr block on day 7. I used a random number generator to generate a number between 1 and 42 to select a 4-hr block and then randomly selected 4 deer to be located during that time interval. I repeated this process until all deer had been assigned to 3 4-hr blocks during the week. Numbers were selected without replacement and I limited the number of 4-hr blocks randomly selected on any given day to 3. During the hunting season I tracked each radio-marked deer hourly during 1 randomly selected 6-hr interval each week. I divided the week into 28 6-hr
intervals (7 days x 4 6-hr intervals/day) and assigned a number to each interval. Number 1 was the first 6-hr interval on day 1 and number 28 was the last 6-hr interval on day 7. I used a random number generator to generate a number between 1 and 28 to select a 6-hr interval, then randomly selected a radio-marked deer for that interval. This process was repeated until all deer had been assigned to one 6-hr interval/week. Numbers were selected without replacement and I limited the number of 6-hour intervals randomly selected on any given day to 2.

To assure independence between observations during the non-hunting season, I took locations for each deer >4 hours apart (Swihart and Slade 1985). Because we were interested in movements of deer in relation to hunters during the hunting season, independence of locations during each 6-hr interval were not important. Deer were classified as alive, censored, or dead (mortality signal). Deer were censored when their transmitter had not been heard for 1 month. Censoring could have been due to radio loss, radio failure, or emigration from the study area. Deer with mortality signals were located so that cause of death could be determined and/or the dropped transmitter could be recovered.

Location estimates were considered unreliable and removed from analysis if the 95% error ellipse exceeded 100 ha. The average error ellipse for each location was 16 hectares (n = 1,276). Seventy-five percent of locations had error ellipses <25 ha. Less than 1% of locations had error ellipses >75 ha (Figure 2).
Figure 1. Location of Amelia Springs hunt club in Amelia County, Virginia.
Figure 2. Distribution of error ellipses (hectares) for 1,276 radio locations of male white-tailed deer in Amelia County, Virginia, March 2004 through January 2006.
Chapter 1. A modified approach to rocket netting white-tailed deer using a remote video system

INTRODUCTION

Capture of white-tailed deer (*Odocoileus virginianus*) is paramount to the success of telemetry studies of the species. Several methods to capture white-tailed deer are reported in the literature, including cannon (rocket) nets (Hawkins et al. 1968), clover traps (Clover 1956), and drop nets (Ramsey 1968). With the exception of clover traps, these methods require a researcher to physically monitor the trap for capture. Rocket netting is one of the most common methods employed to capture white-tailed deer, but it is not without limitations. Hunted deer populations are sensitive to human scent and most attempts to capture deer occur shortly after hunting season. Therefore, researcher proximity to and scent at the trap site may hinder capture. A new technique that avoids these pitfalls employs a rocket net and remote video camera system to aid in the capture of white-tailed deer. Use of remote cameras to study wildlife has increased in recent years (Cutler and Swann 1999). Jacobson et al. (1997) used remote still cameras to census white-tailed deer populations, and video monitoring has been used for food selection (Beringer et al. 2004) and scraping behavior (Alexy et al. 2001) studies. Drop nets monitored remotely by video and triggered remotely by radio signal have been used successfully to capture white-tailed deer (K. L. Gee, The Noble Foundation, personal communication), but the use of remote video to aid in the capture of white-tailed deer has not been described in the literature. I describe a technique for using remote video cameras to aid in the capture of deer, compare the effectiveness of this method to the traditional rocket net method, and describe the potential applications of this technique in future research.
METHODS

I identified potential capture sites large enough to fire a rocket net and baited them with whole kernel corn. When deer began feeding regularly at a site, an 18.2 by 12.1-m knotless nylon net, with 1.3-cm\(^2\) mesh, was placed at the site. The net was stretched out, then pulled back toward the back edge of the net, folding the net upon itself until an 18.2 by 0.3-m line was created. I then placed bait in a concentrated pile 1.5m forward of the back edge of the net at the line’s center. Four recoilless impulse type rockets (patterned after Wildlife Materials and Winn-Star models), mounted on modified fence posts 1.06m above the ground, were attached to the net using 1.2-m shroud lines. The rocket net was weighed down along the back edge with five metal disks weighing 4 kg each to facilitate tangling of deer in the net. I loaded rockets with charges (Winn-Star, Marion, Ill.)\(^1\) comprised of howitzer propellant and an FFG black powder charge used as an igniter. Ignition wires from each charge were attached to an electrical wire, in series, to facilitate simultaneous ignition.

*Traditional on-site method*

For the traditional “on-site” method, I stretched heavy gauge multi-strand electrical wire from the rocket circuit to a camouflaged tent blind or tree stand ≤60 m from the net. A multi-meter tester (A.W. Speery, Hauppauge, N.Y.) was used to test the circuit for continuity. I monitored for deer visually, using a night vision scope (ITT Industries, Roanoke, Va.) after dark. I waited for deer to approach the bait and begin to feed, then fired the net when deer were in the head down position. The net was detonated by completing the circuit with a 6-volt battery. I then proceeded rapidly to the net site and tagged, measured, and radio collared the animal. Deer were physically restrained for

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\(^1\) Reference to trade names does not imply endorsement by the Federal government
5-10 minutes during processing and then released. Handling time began at the moment of detonation and stopped at release of the animal. Trapping, handling and monitoring procedures were established in January 2004 and approved by the animal care committee at VPI and SU (04-028-F&W).

On-site trapping periods were January-March 2004 (winter) and June-August (summer) 2004. I used two observers for the winter period and 1 or 2 observers for the summer period, depending upon availability.

Remote video system method

I used a wireless remote video system (First Witness Video, Mt. Sydney, VA.) powered by a 12-volt deep-cycle battery. The system was comprised of a weatherproof camera, transmitter, receiver, and video monitor (Figure 1.1). The camera incorporated a color camera for daytime display and a black/white night vision camera for night use; the camera automatically sensed lighting conditions to select for day or night mode. The tripod-mounted camera was set according to site conditions. Generally, the camera was set at a 35-degree angle approximately 40 m (average distance) from the rocket net bait pile (Figure 1.2). The camera was hard-wired to a transmitter that was elevated and fastened to a nearby tree oriented toward the receiver site. The receiver station was a vehicle blind 150-300 m away from the rocket net site, depending upon terrain. The video signal could pass through vegetation with reduced reception distance, but not through the ground. A Dakota Alert trail monitoring system (Dakota Alert, Elk Point, S.D.) transmitter was placed 30 cm behind the net aimed at the bait pile. The transmitter was a passive infrared detector activated by a combination of body heat and movement. When activated, it sent a voice signal (e.g., “ALERT ZONE 1”) to a handheld transceiver
to alert the observer in the vehicle. The unit had a 3.2 km range and was battery operated.

When lighting conditions were low (e.g., on a clear night with no moon: 0.001 lux), I used a battery powered infrared illuminator (ITT Industries, Roanoke, Va.) to augment natural light. The infrared light (not visible to deer or human eyes) was detected by the night vision camera and the image transmitted to the video monitor appeared as a white light shining on the targeted area. The illuminator was placed ≤20 m from the rocket net at the same angle as the camera.

After setting up the video system, I ran 20 gauge blasting wire, which was connected to the rocket circuit, to the vehicle blind. Inside the vehicle blind the observer oriented a wireless receiver toward the transmitter and plugged it into a Sony® GVD 800 Video Cassette Player with a 10.1 cm video screen. The receiver operated on the vehicle’s 12-volt power system; an external battery powered the player. I checked the video signal for picture quality and then shut it down to conserve battery power. I used a multi-meter tester to test the circuit for continuity. The handheld Dakota Alert transceiver then was turned on and monitored for an alert signal.

When the observer heard an alert signal, he/she turned on the video player to observe the source of the alert (Figure 1.3). If a target deer was present, the observer watched the video player until the animal was in shooting position and then detonated the rocket net with a Handi-Blaster model HB10 (Blaster Tool & Supply, Frankfort, Ky.). The observer drove or ran to the capture site and processed the animal. An additional person was on standby nearby and called via radio to assist with handling. Processing and handling procedures used were identical to the on-site method.
Cost of the wireless remote video system was US$6,995. Additionally, the Dakota Alert trail monitoring system cost $130 and the ITT Illuminator, $125. Blasting wire was $15/500 feet and a blasting machine $185. A deep-cycle battery and camera tripod added an additional $65. Total system cost above the traditional rocket net set-up cost ($1,400) was just over $7,500.

Remote video trapping periods were August 2004, September 2004, January to March (winter) 2005, and June to August (summer) 2005. I used one or two camera systems depending on observer availability during the remote video periods. The September 2004 period is reported, but not included in the analyses due to attempts to capture yearling and adult bucks only.

RESULTS

I captured 50 deer 59 times during all trapping periods; 2 deer were recaptured during the on-site period, 7 during the remote video period. I captured 15 (5M:10F) deer with the on-site method and 35 (17M:18F) deer with the remote video system. One adult male was captured using the on-site method and 5 adult males (recaptured on-site adult male) were captured using the remote video system. Animals \( \geq 20 \) months at capture were classified adults. Four deer (3M:1F) succumbed to capture myopathy (2 on-site, 2 video). I euthanized 2 (1M:1F) on site, and the remaining 2 males died within 7 days of capture for a capture myopathy rate of 7%. Capture myopathy was determined by gross field examination.

My observers spent 839.4 hours monitoring trap sites for all periods (Table 1.1). On-site observers averaged 4.7 \((n = 20, SE = 0.21)\) hours/night monitoring during winter 2004 and remote video observers averaged 5.7 \((n = 62, SE = 0.34)\) hours/night during
winter 2005. During summer 2004 on-site observers averaged 2.7 (n = 42, SE = 0.15) hours/night monitoring and remote video observers averaged 2.5 (n = 16, SE = 0.32) hours/night during summer 2005. During winter (0.09 deer/hr) and summer (0.17 deer/hr) 2005 the capture rate was roughly double the capture rate in winter (0.05 deer/hr) and summer (0.08 deer/hr) 2004 (Figure 1.4). During January-March 2004 and 2005, 31.6 (n = 3, SE = 21.2) and 14.0 (n = 25, SE = 11.0) hours passed between captures, respectively. For the summer periods, 2004 and 2005 respectively, 11.3 (n = 10, SE = 9.6) and 5.8 (n = 6, SE = 4.6) hours passed between captures. Trapping effort was 18.9 hours/deer and 10.3 hours/deer in winters 2004 and 2005, respectively and 11.3 hours/deer and 5.8 hours/deer respectively, during summer 2004 and 2005. Average handling time was 27.8 (n = 11, SE = 9.4) minutes for the traditional on-site method and 16.8 (n = 34, SE = 10) minutes for the remote video method. Trapping effort during September 2004 was 116.2 hrs/deer and focused only on capture of yearling and adult males.

**DISCUSSION**

My results suggest that the remote video system is more efficient for capturing white-tailed deer than the traditional method of sitting on-site. This was true particularly for adult males who may be more wary of rocket net sites than other age/sex groups. With similar amounts of effort, I captured twice as many deer with the video system as with the on-site traditional method, and with greater comfort to the researcher. With the on-site method, researchers were exposed to the elements, whether in a tent blind or treestand. Generally, attempts by researchers to capture deer are made during the winter when food resources are low. This requires the researcher to endure long hours of cold
temperatures to capture deer. Scent from the observer also was a problem as deer have a highly developed sense of smell (Miller and Marchinton 1994). Although care was taken to orient blinds downwind from bait, many times while using the on-site method researchers experienced the snorting of deer and subsequent flight before the animal reached the trap site potentially indicating an awareness of human presence. The remote video system appears to reduce the human scent problem. I also found that observers were able to stay longer periods of time monitoring a site using the video system.

Although the total cost of the video system is expensive ($7,500), thermal imaging cameras, which could be modified for similar use, cost almost twice as much at $13,257 for a comparable unit (Ditchkoff et al. 2005). Less expensive camera units (<$200) that utilize infrared LED illuminators could be modified for use. The drawback of the less expensive cameras is greatly reduced image quality and camera range (<15m). A less expensive camera could be placed behind the rocket with a narrow view of just the bait pile.

During this study, no animals were injured due to rocket net discharge, and capture myopathy rates for this study were consistent with rates from other studies (Peterson et al. 2003) using rocket nets. A less expensive camera unit probably would not allow for observation of the entire trap area, which may increase the risk of an injurious net discharge. An obvious advantage of the behind the net setup was the ability to determine whether an animal had been marked previously, sparing the animal another stressful capture event and the researcher wasted effort and time reprocessing the animal. Additionally, this setup may make it possible to identify the sex of a deer by the presence of a pedicle in late winter.
Although my experience suggests that a remote video system increases the efficiency of deer capture, I acknowledge that other variables could have influenced my trapping success rates. Different mast conditions, changes in weather, and changes in population size could have caused deer behavior to differ between the time periods compared for the two methods. Researcher experience also likely improved over the study period. However, I believe that summer range conditions between years were similar with an abundance of natural foods available, yet capture rates with remote video were twice the on-site method for the same period. Additional research and field experience with remote video systems likely will confirm the benefits I have presented.

OTHER APPLICATIONS

A remotely monitored video system has many potential applications to aid the capture and monitoring of wild animals. Such a system has the potential to run for months at a time in remote locations using a solar charger to recharge the battery. With a transmitter/receiver range of many miles, rocket nets, cannon nets, drop nets, or any other type of capture device could be monitored from a central location, keeping human influence on the site to a minimum. A potential modification to the system I used would be wireless remote detonation of the rocket net. A remote video system also could be used to monitor nests, den sites, trails, or food resources. I urge our colleagues who are using similar techniques to present results of their work so that others can evaluate benefits of technological advances in wildlife management.
Table 1.1. White-tailed deer trapping and monitoring effort (hours) in Amelia County, Virginia, 2004-05.

<table>
<thead>
<tr>
<th>Net monitoring method</th>
<th>Hours monitoring net</th>
<th>Period</th>
<th>Deer captured</th>
<th>Capture rate (deer/hour)</th>
<th>Capture rate (hours/deer)</th>
<th>Capture mortalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site</td>
<td>94.9</td>
<td>Jan-Mar 2004</td>
<td>5</td>
<td>0.05</td>
<td>18.9</td>
<td>0</td>
</tr>
<tr>
<td>On-site</td>
<td>113.5</td>
<td>Jun-Aug 2004</td>
<td>10</td>
<td>0.08</td>
<td>11.3</td>
<td>2</td>
</tr>
<tr>
<td>Remote Video</td>
<td>6.8</td>
<td>Aug-2004</td>
<td>1</td>
<td>0.14</td>
<td>3.3</td>
<td>0</td>
</tr>
<tr>
<td>Remote Video</td>
<td>232.4(^1)</td>
<td>Sep-2004</td>
<td>2</td>
<td>0.001</td>
<td>116.2</td>
<td>0</td>
</tr>
<tr>
<td>Remote Video</td>
<td>351.1</td>
<td>Jan-Mar 2005</td>
<td>34</td>
<td>0.09</td>
<td>10.3</td>
<td>2</td>
</tr>
<tr>
<td>Remote Video</td>
<td>40.7</td>
<td>Jun-Aug 2005</td>
<td>7</td>
<td>0.17</td>
<td>5.8</td>
<td>0</td>
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<tr>
<td>Total</td>
<td>839.4</td>
<td>59</td>
<td>59</td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

\(^1\) Trapped for bucks only
Figure 1.1. Wireless remote video and monitoring system: (A) day/night camera, (B) wireless transmitter, (C) wireless receiver, (D) Sony video recorder/monitor, (E) Dakota Alert trail monitor, (F) ITT illuminator.
Figure 1.2. Illustration of typical remote video monitored rocket net with angles and distances for maximum observability.
Figure 1.3. Actual view of wireless transmission using the Sony video cassette recorder-monitor. Photo by L. Graves.
Figure 1.4. Comparison of white-tailed deer capture rates for on-site and remote video periods in central Virginia, 2004-05.
Chapter 2. Seasonal home range size and movements of adult male white-tailed deer in relation to hunting pressure on Amelia Springs hunt club.

INTRODUCTION

Home range attributes

Animals do not roam randomly across the landscape, but rather value familiar areas in the sense that they are willing to incur costs to regain or retain them (Stamps 1995). The concept of home range as an area, within which mammals travel to meet their daily needs (Burt 1943, Dice 1952), has been recognized for decades. Specifically, Burt (1943) defined a home range as “…that area traversed by the individual in its normal activities of food gathering, mating and caring for young.” Seton (1929) concluded that white-tailed deer home ranges are the smallest of any deer species in North America, but, in reality, they vary in size according to environmental factors and individual characteristics (Marchinton and Hirth 1984). White-tailed deer usually have an elongated home range pattern, although circular and irregular shaped ranges have been reported (Marchinton and Jeter 1967). Severinghaus and Cheatum (1956) found that home range sizes of northern white-tailed deer tend to be larger and less stable than southern white-tails (see Appendix A).

According to Inglis et al. (1979), site fidelity is strong in resident deer with well established home ranges, whereas young deer that have yet to establish a defined home range or have marginal ranges have less fidelity to their current home range. Tierson et al. (1985) reported deer have strong site fidelity based on social factors and not habitat types. This assertion of site fidelity also is supported by Vanderhoof and Jacobson (1993), who found deer do not shift home ranges to areas with food plots. In a hunted
population, Kilpatrick and Lima (1999) found that, although deer showed strong fidelity
to their annual home ranges, deer shifted their core-area use within home ranges to areas
with permanent cover. Porter et al. (2004) also found that deer had high site fidelity in
suburban areas.

Minimum convex polygon (MCP) methods (Mohr 1947) are one of the oldest and
most commonly used methods for estimating an animal’s home range (Powell 2000).
Because the method frequently is used, comparison of results among studies is possible.
MCP conceptionally is simple, easy to draw, and not constrained by assuming that animal
movements and home range must fit an underlying statistical distribution (Powell 2000).
However, problems with the method are numerous. Minimum convex polygons are
highly sensitive to extreme data points and sample size (# of locations); it assumes
animals use their home range evenly, it can incorporate large areas that never are used,
and it does not provide information about core areas of use (Powell 2000). Home ranges
calculated with differing numbers of data points might not be comparable because the
longer the survey, the larger the home range may become (Samuel and Fuller 1996).
MCP emphasizes only the unstable boundary areas of a home range and ignores the
interior structure and core areas of use, which are of most interest to researchers (Powell
2000).

The kernel density method (KDE) is a better estimator than MCP in calculating
core area use (Worton 1989, Seaman et al. 1999). The kernel density estimator produces
an unbiased density estimate directly from data not influenced by grid size or placement
(Silverman 1986). The kernel estimator produces a utility distribution of locations on the
landscape by taking each location and covering it with a 3-dimensional mound, the
kernel, whose volume is 1 and whose shape and width, are chosen by the researcher. The width of the kernel (band width) often is referred to as the smoothing parameter and is used to control the amount of variation in the estimate. Band width can be held constant for a set of data (fixed kernel) or it can vary (adaptive kernel), such that points are covered with kernels of different widths ranging from low, broad kernels for widely spaced points, to sharply peaked, narrow kernels for tightly packed points. Narrow kernels reveal small-scale details in the data, but tend to highlight measurement error, whereas wide kernels smooth out sampling error, but hide local detail (Powell 2000). Because each kernel is a density, the resulting estimate is a true probability density function itself (Worton 1989). For non-normal distributions, least squares cross-validation can be used to determine band width and to select the band widths with the minimum estimated error (Powell 2000).

**Male white-tailed deer movements in relation to hunting pressure**

Knowledge of deer responses to hunting pressure may provide insight to mangers regarding the duration, intensity, and framework of hunt programs (Kilpatrick and Lima 1999). This is especially useful in Quality Deer Management (QDM) programs, where a goal of the harvest strategy is to harvest “older, smarter” animals that have larger antlers. Several studies examined deer movements in relation to firearms hunting in rural landscapes (Marshall and Whittington 1969, Kammermeyer and Marchinton 1976, Pilcher and Wampler 1982, Kufeld et al. 1988, Root et al. 1988, VerCauteren and Hygnstrom 1998), and one study (Kilpatrick and Lima 1999) reported deer movements during an archery hunt in an urban landscape. The results of these studies are contradictory. Some studies conclude that deer remain within established home ranges

The duration of hunting pressure assessed also was highly variable. A short duration hunt is defined as lasting 14 days or less. Short time duration hunts that lasted 2 to 10 days were examined by Van Etten et al. (1965), Autry (1967), Kammermeyer and Marchinton (1976), Kufeld et al. (1988) and Root et al. (1988). These studies investigated the immediate response of deer to hunting pressure, but did not consider deer behavior during extended hunts (Kilpatrick and Lima 1999). Only the studies of Kilpatrick and Lima (1999) in Connecticut and Kufeld et al. (1988) in Colorado looked at longer duration hunting effects on deer movements. Studies that have assessed male movements in response to heavy hunting pressure are contradictory and the differences may be related to location and habitat with areas of heavy understory cover accommodating more hunters without altering male deer movements versus areas with sparse understory cover (Root et al. 1988). Van Etten et al. (1965) reported that male home ranges in Michigan increased when subjected to hunting. Conversely, Autry (1967) found male home ranges in Illinois decreased in response to hunting pressure. Root et al. (1988) concluded that males in Missouri did not alter their movement patterns, but may have changed their behavior in other ways, like short-term hiding, which may not have been detected by telemetry. Kilpatrick and Lima (1999) assessed deer movements relative to annual home
ranges and concluded that deer do not alter their home range in response to hunting. Autry (1967), Root et al. (1988), and VerCauteren and Hygnstrom (1998) compared core area use with and without hunting and reported shifts of core areas to permanent cover or refuges. There are no reports examining adult (≥ 2.5 years) buck movements in relation to hunting across the full length and weaponry seasons (archery, muzzleloader, and modern firearm).

METHODS

Home Range Analysis

I estimated home range sizes with MCP and kernel methods. I used an animal home range estimator extension (HRE) designed for ARCGIS© (ESRI, Redlands, California, USA) to estimate home range because it allowed the use of the MCP and kernel method. The software program ARCGIS© was used with an animal home range estimator extension developed by Rodgers and Carr (1998), which was useful because of its full integration with all ARCGIS© functions and extensions. The extension integrates many types of spatial data and allows for complex queries and selections. UTM coordinates for the locations of each buck were plotted in ARCGIS© then a home range was calculated. I classified male deer as adults if they were ≥20 months of age. Deer this age had survived their first hunting season with visible antlers and I believe were likely more wary of hunters.

I estimated home range size using 3 estimators: user defined h = 0.4, least squares cross validation (LSCV) adaptive kernel, and LSCV fixed kernel. I chose the adaptive kernel home range estimator with a user defined smoothing factor (h) of 0.4 for my analysis. This method was suggested by the co-author (A.R. Rodgers, Ontario Ministry of
Natural Resources, personal communication) of the HRE extension as another estimation method. The commonly reported LSCV method under smooths the utilization distribution (Sain et al. 1994, Rodgers and Carr 1998) thereby overestimating the size of the home range. Based on my personal observations in collection of the telemetry data the user defined method best matched the size of male deer home ranges.

I estimated annual and seasonal home range sizes for adult male white-tailed deer and I calculated 95% and 50% contours for all home ranges. Annual home range size was defined as encompassing a 1-year period or until loss of signal. Seasonal home ranges were divided into 2 seasons: non-hunting season, which was January-September and hunting season, which was October to January. Deer that did not have a sufficient number of locations from both non-hunting and hunting seasons, based upon kernel asymptote analysis in software program ABODE (Laver 2005), were excluded from annual home range size estimation. I chose to exclude 3 excursion points for deer 147 that may have been due to an outside factor, possibly a dog, which caused the deer to go out of his normal area of use. I found the deer in a large swamp 3.7 km outside its normal home range. I suspect the swamp provided escape cover. I recorded 2 additional locations as the deer moved back to his normal summer range; no subsequent abnormalities were recorded for this deer until dispersal.

Hunter/deer interactions

During the fall hunting season (October-January), I recorded both deer and hunter locations. I tracked deer as described in the general methods section. No comparable data were collected during the non-hunting season. Hunters were given a Garmin® e-Trex or 12 series GPS unit and a log book to track and record their locations while hunting.
Hunters logged their location while hunting each day, one location at each spot hunted (i.e. location at morning stand, location at evening stand). Hunters were asked to write in their log book the waypoint number, amount of time hunted, and date at each marked “waypoint.”

Factors used in analysis

Unless otherwise noted, the significance level was set at $\alpha = 0.05$. I used the Anderson-Darling test to test for normality and I log transformed data found to be non-normal. I used an F-test to test for unequal variance.

Year effect- Seasonal home ranges were tested using students t-test and did not differ ($p > 0.05$) between years, thus I combined years in the analysis of home range data.

Season effect, age effect and seasonal* age effect- I used a 2-way ANOVA (GLM; MiniTab Inc., 2005) to examine home ranges by season, age, and season* age interaction to test whether the variables interacted to produce a greater or lesser effect than what would be expected from the effects individually. I used a paired t-test to compare non-hunting and hunting home range size by season. This was done to account for the individual variability among deer. Differences in non-hunting and hunting home ranges by age class (Adult, Juvenile), were tested in the same manner.

Hunter/Deer interactions- I plotted all hunter locations and deer locations during the course of the hunting season. I used a Student’s t-test to check for differences in hunting pressure between years and I used Multiple Response Permutation Procedure (MRPP) to determine if deer increased their movements during hunting season (Mielke and Berry 2001). MRPP was used to calculate the average day and night movements of male deer.
MRPP is useful for analyzing categorical and environmental data because it uses distribution-free procedures. Rather than depending on some assumed distribution, MRPP uses permutations of the actual data to calculate the probability that the observed grouping of observations could be due to chance (Slauson et al. 1994). I then used a paired t-test to compare MRPP calculated average day/night distances moved for male deer during the hunting seasons. I used Chi-square analysis to test for differences in the proportion of male deer camera captures in September (non-hunted) versus October-November (hunted) each year. The camera captures were a byproduct of 23 remote cameras I used to assess male deer density (see Chapter 3). To account for daylight differences during the periods, I calculated the average amount of daylight/darkness during each period using a sunrise/sunset table (United States Naval Observatory 2006), then added an hour for legal hunting hours, 30 minutes before sunrise to 30 min past sunset, to determine if a buck capture was during day or night.

RESULTS

I monitored 20 male white-tailed deer (5 adults, 15 juveniles) from March 2004 until January 2006 over the course of 2 deer hunting seasons. Seven of 15 juveniles (47%) dispersed from the study area with a mean emigration date of October 13 (Table 2.1). The average distance dispersed from geometric center of home range was 6.1 kilometers. All dispersing males (7) were either hunter harvested (6) or died from natural causes (1). Five of 7 (71%) were harvested within 1 month of dispersal. One was killed during the following year’s archery season and the remaining male died of undiagnosed natural causes within 4 months of dispersal. Hunter harvest mortality for marked deer was 50% (10 of 20) and natural mortality was 15% (3 of 20). All other deer (7) were
alive when their radio signal was lost and had not shown up in harvest as of January 2006 (Table 2.1).

**Home Range Size**

*Annual*

I used data from March 2004-December 2005 to calculate annual home ranges for male deer (Table 2.2). MCP 95% adult and juvenile home ranges ranged from 2.1 to 3.1 km² and 0.3 to 2.0 km², respectively. MCP 50% contours for adults spanned 0.3 to 0.4 km², whereas juveniles spanned 0.06 to 0.4 km². Adaptive kernel (95% contour) annual home range sizes ranged from 2.7 to 3.9 km² for adults and 0.3 to 3.8 km² for juveniles. Fifty percent contour adaptive kernel annual home range sizes spanned 0.2 to 0.7 km² for adults and 0.06 to 0.3 km² for juveniles.

*Seasonal*

I used home range data from March -September 2004 and January-September 2005 to calculate the non-hunting season home range (Table 2.3) of male deer. Adult home range sizes varied between 1.8 and 3.1 km² for 95% contour MCP, and from 1.7 to 3.9 km² for 95% contour adaptive kernel. Fifty percent contour non-hunting home range size for adults ranged from 0.1 to 0.3 km² for MCP and 0.2 to 0.6 km² for kernel. Ninety-five percent MCP and adaptive kernel juvenile, non-hunting season home range size ranged from 0.2 to 1.4 km² and 0.2 to 2.0 km², respectively. Juvenile 50% non-hunting season home range varied between 0.02 and 0.2 km² for MCP and 0.05 and 0.2 km² for adaptive kernel.

I used data from October-January 2004-05 to calculate male deer hunting season home ranges (Table 2.3). Adult home range size during the hunting season ranged from
0.8 to 1.8 km$^2$ for 95% MCP and 1.0 to 2.6 km$^2$ for 95% kernel. At the 50% contour the range was 0.08 to 0.6 km$^2$ for MCP and 0.02 to 0.06 km$^2$ for adaptive kernel. Hunting season home range size for juveniles (95%) varied between 0.1 and 2.3 km$^2$ for MCP and 0.2 and 5.4 km$^2$ kernel. At the 50% contour the values were 0.03 to 0.7 km$^2$ for MCP and 0.06 to 1.6 km$^2$ for adaptive kernel.

**Season and age effects**

Home range size among male deer (ages combined) did not differ between hunting and non-hunting seasons for 95% or 50% contour MCP and Kernel estimators (Table 2.4). Seasonal (hunting vs. non-hunting) juvenile home ranges were smaller than adult home range size for 95% MCP and kernel estimators and for 50% contour MCP and adaptive kernel (Table 2.4). The interaction between season and age was not significant at either the 95% contour or the 50% contour regardless of the estimator used.

**Hunter/Deer interactions**

Club members reported hunting 1,007 hours in 2004 and 826 hours in 2005. Hunters averaged 12.7 calendar days afield during the 2004 hunting season and 12.0 days in 2005. The average number of hours hunted per day was 4.1 in 2004 and 4.3 in 2005. Combined years average time spent morning hunting was 3.7 hours ($\bar{x} = 3.8$) and 2.9 hours ($\bar{x} = 2.6$) during the evening hunt.

The average distance male deer moved at night versus day during the hunting season did not differ by age (Table 2.5) during the hunting season. Hunter and deer locations (individually color coded) during hunting seasons 2004 (Figure 2.1) and 2005 (Figure 2.2) illustrate how radio-tagged deer concentrated their movements in areas of little or no hunter use during the hunting season. Five of 20 marked male deer were seen
by Amelia Spring’s hunters and 4 subsequently were harvested. Chi-square analysis of
deer movements using camera captures from September (non-hunting) and October-
November (hunting) for 2003, 2004 and 2005 (Figures 2.3–2.5) were not statistically
different except for the 2003 periods (Table 2.6).

DISCUSSION

Dispersal

As part of a QDM program, restriction of harvest to older animals should result in
lower mortality rates on younger deer than on older deer. Morgan et al. (1995) reported
an 11% mortality rate of maturing males that stayed on QDM property in South Carolina
and a 100% mortality rate (due to hunting) when juveniles dispersed from the QDM area,
matching the juvenile dispersal results of this study. Also in that study, dispersal
distances to off-site harvest locations ranged from 4.1 to 21.6 km. As in my study,
Rosenberry et al. (1999) reported a mean dispersal distance of 6 km for juvenile bucks in
Maryland; hunting accounted for 78% mortality among 33 dispersing juveniles.
Approximately 50% of all yearling males disperse from their natal range (Hawkins et al.
1971, Nixon et al. 1991, Nelson 1993, Rosenberry et al. 1999), which can lead to
changes in population sizes (Hawkins et al. 1971) and sex ratios (Kamermeyer and
Marchinton 1976, Marchinton, 1982).

Hölzenbein and Marchinton (1992b) stated that dispersal behavior is widely
accepted as an avoidance of intense inbreeding (parent-offspring, sibling mating). Long
et al. (2005) suggests that dispersal of juveniles may not be correlated with population
density or forest cover, rather sociobiological. Maternal aggression (Hölzenbein and
Marchinton 1992b) or intrasexual competition among males (Kamermeyer and
Marchinton 1976; Wahlström 1994; Hjeljord 2001; Rosenberry et al. 2001) likely increases the dispersal rate of juveniles. Several studies have suggested that the presence of the dam frequently leads to the son’s emigration (Downing et al. 1969, Ozoga and Verme 1985, Marchinton et al. 1990). Ozoga and Verme (1985) found that yearling males suffered more aggressive encounters from female relatives than from unrelated females. Removal of the dam therefore can lead to a yearling staying in his natal range and increasing his survival rate (Hölzenbein and Marchinton 1992a). The increased harvest pressure on females (dam harvest) provided by QDM may lead to more males being retained in a population. Springtime dispersal of males, due to maternal aggression (Hölzenbein and Marchinton 1992a), was not detected during my study.

Adult male aggression toward juveniles is thought to be due to competition for mates (Hawkins and Klimstra 1970, Kammermeyer and Marchinton 1976, Nixon et al. 1991, Wahlström 1994, Hjeljord 2001). Wahlström (1994) also suggested if food was the source of aggression then all juveniles would be evicted regardless of sexual majority. I have no information regarding juvenile female emigration from the study site, but other studies suggest they commonly do not disperse from their natal ranges (Dobson 1982, Nelson and Mech 1984). All juvenile emigration from Amelia Springs hunt club happened in early fall as the level of testosterone in males grew, suggesting male aggression as the proximate cause.

Much has been reported regarding emigration of juvenile males from specific populations, but scant literature exists regarding immigration. Although this study was not designed to detect immigration, Rosenberry et al. (1999) reported a net loss of only 8 males (39 emigrants, 31 immigrants), after taking immigration into account. If
stockpiling bucks into an area is possible, it likely hinges upon this dispersal equilibrium. After leaving their natal range, juvenile males usually take routes that avoid resident animals (Strandgaard 1972, Nixon et al. 1991, Wahlström and Liberg 1995, Nelson 1998) and avoid high deer density areas (Hjeljord, 2001). Based on the high densities of males on Amelia Springs (see Chapter 3), I would expect dispersing juvenile males to keep moving through the study area keeping intact an emigration imbalance. The result would be the inability to stockpile more bucks onto the study site. I do not know if emigration and immigration rates are equal on Amelia Springs but the exchange of individuals between populations is important for gene flow.

No adult male emigrated was detected from the study site (Table 2.1). This was not unexpected; Inglis et al. (1979) reported adult deer with established home ranges have strong site fidelity. Tierson et al. (1985) also reported deer have strong site fidelity based on social grouping. It appears that once a male reaches adulthood the likelihood of dispersal is negligible. This appeared to be true for Amelia Springs adult males.

Some studies have found that trophy hunting (i.e. taking only exceptionally sized animals) or quality deer hunting can have a detrimental affect on body size and antler quality. Coltman et al. (2003) reported declines in male bighorn sheep (*Ovis canadensis*) weight and horn size due to trophy hunting. Shea and Vanderhoof (1999) reported that mean antler size of 2.5 year old male deer in Florida decreased due to selective harvest of large 1.5 year old males while protecting small antlered 1.5 year olds. However, Strickland et al. (2001) suggested that selective harvest criteria, such as with QDM, can increase average antler size by affecting the age structure of harvested deer, but cautioned that antler degradation also can occur due to environmental conditions and harvest
mistakes (e.g., taking large antlered 1.5 year olds). This is a real concern on Amelia Springs. Excessive harvest of exceptional antlered 1.5 year old males could lead to a degradation of overall antler size. Selective harvest controls (18 inch beam length) implemented in 2003 should retard severely the harvest of large antlered yearlings because few yearling males have antlers of that size. Gene flow in and out of the population should increase genetic diversity and prevent the scenario described above.

*Home Range size*

Comparable literature used hereafter are MCP home range estimates unless otherwise noted. I found one comparable study of home size of male deer in the Piedmont physiographic province. Marshall and Whittington (1969) reported a hunting season home range of 1.45 km\(^2\) for a single yearling buck on Clark Hill wildlife management area, Georgia. The results of my study are the first to document annual and seasonal home range size of male deer for the Piedmont physiographic province. Coastal Plain home ranges, which should be most similar, averaged 3.08 km\(^2\) for 17 males in South Carolina (Koldyke 1999). All age Amelia Springs’ males averaged 1.74 km\(^2\) annually, almost half the size of Coastal Plain bucks; I suspect this difference may be habitat related. Amelia Springs is predominately even age pine plantation of various ages. Stems per acre in pine plantations are greatest in stands <10 years old and stem density decreases with age (Daniel et al. 1979). Clear-cut stands temporarily improve range quality, whereas the older stands produce less food for deer during the middle and latter stages of the harvest rotation (Whittington 1984). Food plots (<1%) and oak drainages (<5%), remaining from best management forestry practices, were scattered throughout Amelia Springs and deer did not have to go far to move from areas of dense cover to
open feeding areas. Marchinton and Hirth (1984) suggested that deer movements in relatively open habitats are larger than those in heavily vegetated areas. Harestad and Bunnell (1979) reported that ruminant herbivores have decreased home range size because of seasonal fluctuations of food due to productivity of habitat. Kilgo and Labisky (1997) reported that drops in crude protein below maintenance levels in female deer could cause home range size to decrease, a behavior adapted to reduce physiological expenditures during periods of nutritional stress. I suspect, although I have no evidence to support, that the home range of deer in other parts of Amelia County which are 70% forested:25% agriculture (USGS 2006), would be similar in size to Coastal Plain home ranges due to the mix of open land and forest. Coastal Plain land use according to Bailey (1995) was 60% forested:40% agriculture.

The annual home range size of 0.93 km² for juvenile deer on Amelia Springs was smaller than expected when compared to Coastal Plain South Carolina, where annual home range size averaged 3.89 km² (Rudisail 2005). I believe that a combination of marginal habitat, as discussed earlier, the avoidance of hunters (Hawkins et al. 1971, Kammermeyer and Marchinton 1976, Pilcher and Wampler 1982, and Root et al. 1988), and high densities of adult males (see Chapter 3), which theoretically should result in aggression toward juveniles (Hawkins and Klimstra 1970, Kammermeyer and Marchinton 1976, Nixon et al. 1991, Wahlström 1994, and Hjeljord 2001.), restrict the annual movements of juveniles. In addition, the intensive harvest of females under QDM (see Chapter 4), may result in a disproportionate number of male deer. Holzenbein and Marchinton (1992b) reported home range size of orphaned juveniles were smaller than
non-orphans, probably due to orphans tracing their mother’s movements (home range) leading to a smaller home range size.

Juvenile non-hunting season home range size on Amelia Springs averaged 0.63 km². My results follow the pattern where home range size is smallest during the non-hunting season (Kroll 1994). Others have associated small home ranges with high density populations (Marchinton and Jeter 1967, Marshall and Whittington 1969, Ellisor 1969). Mean summer home range size of juvenile bucks for a coastal South Carolina population was 1.89 km² (Rudisail 2005).

Juvenile home range size (0.80 km²) during hunting season on Amelia Springs was small as well. Several studies (Nelson and Mech 1984, Tierson et al. 1985, and Kroll 1994) have reported that buck home range size get substantially larger during the fall breeding season, but this did seem to occur with Amelia Springs’ juvenile males. Hunting season home range size was only slightly larger (0.17 km²) than non-hunting season. I expected juvenile hunting season home range size to be the same or slightly smaller than adults (1.39 km²), based on studies from the Coastal Plain of South Carolina. It may be that the high density of adult males in the Amelia Springs population precludes juveniles from much movement other than basic life functions.

The larger annual and seasonal home range sizes for adults on Amelia Springs compared juveniles were not totally unexpected. Inglis et al. (1979) and Kroll (1994), also reported this pattern and noted that bucks home range size increases with age. Annual home range sizes of adult bucks in Coastal Plain of South Carolina ranged from 3.08 to 4.08 km² (Koldyke 1999, Rudisail 2005), much larger than the 2.55 km² average of Amelia Springs.
Clearly home range sizes of Amelia Springs’ bucks of all ages were smaller than those reported in the literature in South Carolina. This may be a function of habitat as discussed earlier or may be the norm for the Piedmont physiographic province as I have no Piedmont reports to compare to. I believe it to be the former. Amelia Springs is not a common, naturally occurring habitat in the Piedmont physiographic province, and, as stated earlier, it appears that Amelia Springs habitat is of lower quality than the habitat of Amelia County.

**Hunting effects on deer movements**

The effects of hunting on deer movements are difficult to quantify. In a Georgia study, deer did not leave their home range during hunting season (Marshall and Whittington 1969), but Kammermeyer and Marchinton (1976) found mass movements during hunting season in the same state. What is clear is that deer that have a strong fidelity to their home range find areas within their home range and hide in areas of dense cover or areas of little hunting pressure (Autry 1967, Kilpatrick and Lima 1999, Kilpatrick et al 2002). Millspaugh et al. (2000) reported the same reaction to hunting for elk (*Cervus elaphus*) in South Dakota. On Amelia Springs, this seems to be the case as well, as indicated on the deer/hunter location overlays (Figures 2.1 & 2.2); these show that deer spent most of their time in areas less used by hunters. Kammermeyer and Marchinton (1976) suggest that habitat conditions, juxtaposition of refuges, and past history of hunting play a role in deer response to heavy hunting pressure. In the case of Amelia Springs, hunters generally hunt from the same permanent stands in the same locations repeatedly over time. Thus, refuges at Amelia Springs are those areas that are not hunted continually, namely, areas that show the greatest concentration of deer.
locations with little hunter activity around them. Couple that with the dense habitat of Amelia Springs and it seems apparent how deer can hide and escape harvest relatively easily. Only 25% of the marked animals were seen by hunters, lending creditability to the “elusiveness of bucks” on Amelia Springs. I found no difference in day and night movements of bucks, indicating that deer may hide in areas not subjected to hunting pressure or where pressure was not sufficient to cause extensive nocturnal movements.

As mentioned previously, home range size of male deer was smaller than expected, possibly due to habitat type and hunting pressure (Kammermeyer and Marchinton 1976). Kroll (1994) concluded that mature bucks avoid hunted areas entirely in as little as three days into the season, and avoid permanent stand areas all together. One deer on Amelia Springs, a 3.5 year old male, moved his home range 2 weeks into the 2004 hunting season, 2 km from a heavily hunted area to a low hunting pressure area. He remained in this adopted home range until 2 weeks after hunting season ended, then moved back and stayed in his original home range until his death due to hunting in 2005. I suspect these movements were due to hunting, but they did not occur in 2005 and no other animal made a similar move. This was the oldest animal radio tagged during the study.

I found no differences in the average movements of males during the day and at night during the hunting season. This was unexpected as some studies (Autry 1967, Root et al. 1988, Kilpatrick and Lima 1999) have shown that deer change movement patterns during the hunting season, and suggest that deer move less during the day and more at night.
No differences in hunting pressure occurred during the two years of the study, which suggests this is the normal pattern of interaction. My personal observations of hunters on Amelia Springs lead me to believe that the hunter location information was somewhat incomplete in both years, but still accurately reflected how hunters use the landscape on Amelia Springs hunt club.

The camera capture data (Table 2.6) were inconclusive, 2003 suggested that bucks were more active in October-November (hunting season) than in September (non-hunting season) and 2004-05 suggested no differences in movements during either period.
Table 2.1. Known fates of male white-tailed deer Amelia County, Virginia, March 2004 – January 2006.

<table>
<thead>
<tr>
<th>Deer #</th>
<th>Age Class¹</th>
<th>Dispersed?</th>
<th>Distance Dispersed(km)</th>
<th>Fate</th>
</tr>
</thead>
<tbody>
<tr>
<td>204</td>
<td>Adult</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>325</td>
<td>Adult</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>363</td>
<td>Adult</td>
<td>N</td>
<td>-</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>383</td>
<td>Adult</td>
<td>N</td>
<td>-</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>963</td>
<td>Adult</td>
<td>N</td>
<td>-</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>147</td>
<td>Juvenile</td>
<td>Y</td>
<td>16.7</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>163²</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>163</td>
<td>Juvenile</td>
<td>Y</td>
<td>2.0</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>184</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>224</td>
<td>Juvenile</td>
<td>Y</td>
<td>8.2</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>262</td>
<td>Juvenile</td>
<td>Y</td>
<td>3.2</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>284</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>303</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>EHD³</td>
</tr>
<tr>
<td>344</td>
<td>Juvenile</td>
<td>Y</td>
<td>3.7</td>
<td>Natural⁴</td>
</tr>
<tr>
<td>863</td>
<td>Juvenile</td>
<td>Y</td>
<td>7.5</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>884</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>904</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>924</td>
<td>Juvenile</td>
<td>Y</td>
<td>1.6</td>
<td>Hunt kill</td>
</tr>
<tr>
<td>944</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Vehicle kill</td>
</tr>
<tr>
<td>984</td>
<td>Juvenile</td>
<td>N</td>
<td>-</td>
<td>Alive</td>
</tr>
</tbody>
</table>

¹Age class: Adult=20+ months, Juvenile=0-20 months
²Transmitter was refurbished and used on different deer
³Unconfirmed epizootic hemorrhagic disease
⁴Undiagnosed natural causes
Table 2.2. Mean annual home range size (km²; S.E.) for male white-tailed deer Amelia County, Virginia, March 2004 – December 2005.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>N</th>
<th>95% MCP</th>
<th>50% MCP</th>
<th>95% Kernel</th>
<th>50% Kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>4</td>
<td>2.5(0.2)</td>
<td>0.5(0.07)</td>
<td>3.4(0.2)</td>
<td>0.5(0.06)</td>
</tr>
<tr>
<td>Juvenile</td>
<td>12</td>
<td>0.9(0.1)</td>
<td>0.1(0.03)</td>
<td>1.2(0.2)</td>
<td>0.2(0.03)</td>
</tr>
</tbody>
</table>

¹Age class: Adult=20+ months, Juvenile=0-20 months
Table 2.3. Mean seasonal home ranges (km$^2$; S.E.) for male white-tailed deer Amelia County, Virginia, March 2004 – December 2005.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>N</th>
<th>Season</th>
<th>95% MCP (km$^2$)</th>
<th>50% MCP (km$^2$)</th>
<th>95% Kernel (km$^2$)</th>
<th>50% Kernel (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>5</td>
<td>Non-hunt</td>
<td>1.6(0.4)</td>
<td>0.3(0.04)</td>
<td>2.3(0.5)</td>
<td>0.4(0.07)</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td>0.6(0.1)</td>
<td>0.1(0.03)</td>
<td>0.8(0.1)</td>
<td>0.1(0.02)</td>
</tr>
<tr>
<td>Juvenile</td>
<td>4</td>
<td>Hunt</td>
<td>1.3(0.2)</td>
<td>0.4(0.1)</td>
<td>2.0(0.3)</td>
<td>0.5(0.1)</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td>0.8(0.3)</td>
<td>0.2(0.1)</td>
<td>1.5(0.8)</td>
<td>0.4(0.2)</td>
</tr>
</tbody>
</table>

1Age class: Adult=20+ months, Juvenile=0-20 months
Table 2.4. Effects of season and age (ANOVA) on home range size of male white-tailed deer at the 95% and 50% fixed-kernel and minimum convex polygon (MCP) contours, in Amelia County, Virginia, March 2004 – December 2005.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Source</th>
<th>d.f.</th>
<th>SS(^1)</th>
<th>MS(^1)</th>
<th>F-Value</th>
<th>Probability &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% MCP</td>
<td>Season(^2)</td>
<td>1</td>
<td>0.111</td>
<td>0.0001</td>
<td>0.00</td>
<td>0.988</td>
</tr>
<tr>
<td></td>
<td>Age(^3)</td>
<td>1</td>
<td>6.529</td>
<td>6.035</td>
<td>11.58</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Season*Age</td>
<td>1</td>
<td>0.106</td>
<td>0.106</td>
<td>0.20</td>
<td>0.656</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>22</td>
<td>11.464</td>
<td>0.521</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95% Kernel</td>
<td>Season(^2)</td>
<td>1</td>
<td>0.369</td>
<td>0.072</td>
<td>0.12</td>
<td>0.728</td>
</tr>
<tr>
<td></td>
<td>Age(^3)</td>
<td>1</td>
<td>5.685</td>
<td>5.180</td>
<td>8.84</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Season*Age</td>
<td>1</td>
<td>0.157</td>
<td>0.157</td>
<td>0.27</td>
<td>0.610</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>22</td>
<td>12.895</td>
<td>0.586</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% MCP</td>
<td>Season(^2)</td>
<td>1</td>
<td>0.951</td>
<td>0.347</td>
<td>0.43</td>
<td>0.517</td>
</tr>
<tr>
<td></td>
<td>Age(^3)</td>
<td>1</td>
<td>8.214</td>
<td>7.596</td>
<td>9.48</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Season*Age</td>
<td>1</td>
<td>0.130</td>
<td>0.130</td>
<td>0.16</td>
<td>0.690</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>22</td>
<td>17.638</td>
<td>0.801</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% Kernel</td>
<td>Season(^2)</td>
<td>1</td>
<td>1.821</td>
<td>0.960</td>
<td>1.65</td>
<td>0.213</td>
</tr>
<tr>
<td></td>
<td>Age(^3)</td>
<td>1</td>
<td>5.568</td>
<td>5.064</td>
<td>8.69</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Season*Age</td>
<td>1</td>
<td>0.163</td>
<td>0.163</td>
<td>0.28</td>
<td>0.602</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>22</td>
<td>12.824</td>
<td>0.582</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Corrected for small sample size  
\(^2\) Hunting season, non-hunting season  
\(^3\) Adult, juvenile
Table 2.5. Average distance moved during the day and at night (m, S.E.) for male white-tailed deer, Amelia County, Virginia October - January 2004-05.

<table>
<thead>
<tr>
<th>Age Class&lt;sup&gt;1&lt;/sup&gt;</th>
<th>N</th>
<th>Day&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Night&lt;sup&gt;3&lt;/sup&gt;</th>
<th>t-stat</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>12</td>
<td>747.7(131.4)</td>
<td>680.5(115.6)</td>
<td>-0.81</td>
<td>0.21</td>
</tr>
<tr>
<td>Adult</td>
<td>5</td>
<td>732.7(164.3)</td>
<td>701.9(160.8)</td>
<td>-0.50</td>
<td>0.32</td>
</tr>
<tr>
<td>Juvenile</td>
<td>7</td>
<td>758.9(203.5)</td>
<td>665.2(172.0)</td>
<td>-0.67</td>
<td>0.26</td>
</tr>
</tbody>
</table>

<sup>1</sup>Age class: Adult=20+ months, Juvenile=0-20 months
<sup>2</sup>Day: 30 min. before sunrise to 30 min. after sunset
<sup>3</sup>Night: 30 min. after sunset until 30 min. before sunrise
Table 2.6. Comparison of September$^1$ and October-November$^2$ day and night camera captures of male white-tailed deer Amelia County, Virginia 2003-05.

<table>
<thead>
<tr>
<th>Year</th>
<th>Period</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>September</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>2003</td>
<td>October-November</td>
<td>19</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>$59$ total trap nights/day $\chi^2=5.88, \ P = 0.01^3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>September</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>2004</td>
<td>October-November</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>$60$ total trap nights/days $\chi^2=0.67, \ P = 0.41^3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>September</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>2005</td>
<td>October-November</td>
<td>41</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>$65$ total trap nights/days $\chi^2=0.17, \ P = 0.67^3$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$=Non-hunting, $^2$=Hunting
$^3$=Day versus night
Figure 2.1. Male deer and hunter locations during the 2004 hunting season (October-January), Amelia Springs hunt club, Amelia County, Virginia.
Figure 2.2. Male deer and hunter locations during the 2005 hunting season (October-January), Amelia Springs hunt club, Amelia County, Virginia.
Figure 2.3. Timing of antlered white-tailed deer captures during September 2003 and October-November 2003 at Amelia Springs hunt club, Amelia County, Virginia.

Figure 2.4. Timing of antlered white-tailed deer captures during September 2004 and October-November 2004 at Amelia Springs hunt club, Amelia County, Virginia.
Figure 2.5. Timing of antlered white-tailed deer captures during September 2005 and October-November 2005 at Amelia Springs hunt club, Amelia County, Virginia.
Chapter 3. Deer density estimates on Amelia Springs hunt club

INTRODUCTION

Sex Ratios under QDM

Sex ratios where Quality Deer Management (QDM) is practiced successfully should have a buck:doe ratio of 1:2 to 1:3 (Adams 1985). This sex ratio is thought to maintain population density below carrying capacity, and balance the provision of a suitable proportion of harvestable deer with maintenance of an adequate number of does for recruitment purposes (Newsom 1984). Buck:doe ratios <1:2 are characteristic of trophy deer management programs where only the largest bucks are taken (Brothers and Ray 1982, Newsom 1984). Until recently, most management strategies in the southeastern United States were designed to maximize harvest (Newsom 1984). A maximum productivity harvest program requires the harvest of both sexes and all ages of deer, and an annual kill of roughly 35% of the population (Wilson and McMasters 1974). Deer sex ratios will be >1:3 (buck:doe) as the herd approaches the biological carrying capacity.

Population density estimates

Mark-Recapture

Population estimates often are used as an important determinant in making wildlife management decisions such as hunting season length, bag limits, and harvest moratoriums. Numerous methods have been used to estimate population size including comprehensive censuses, line-transect surveys, and aerial surveys. Mark-recapture estimates, however, provide a more robust estimate of population size (Pollock and Otto 1983, Nichols 1992). Biologists and ecologists have long recognized that, in free-ranging
populations, it is impossible to count every animal (i.e., obtain a census of the population). Marking or tagging is used to distinguish individuals as 2 sub-samples of the population, and thus the proportion of recaptures to new captures, or marked to unmarked, can be used to estimate the number of animals in the population (Chao 2001).

Several different methods have been developed to calculate population estimates from mark-recapture data. The Lincoln-Peterson method was the earliest estimator developed and is defined by the equation 

\[
\hat{N} = \frac{n_1 \times n_2}{m_2}
\]

where \(n_1\) is the number of animals captured and marked in the first sample, \(n_2\) is the number of animals captured in the second sample and \(m_2\) is the number of animals recaptured in the second sample (Krebs 1999). The obvious limitation to this method is the inability to incorporate >1 capture period at a time.

There are several assumptions associated with basic population estimators like Lincoln-Peterson. The most problematic for many field studies are demographic and geographic closure (White et al. 1982). These assume a static population size during the time of the sampling, meaning there are no births or deaths, and no immigration or emigration. An additional assumption is that each animal has a constant and equal probability of capture (\(\hat{P}\)) on each trapping occasion, and capturing and marking an animal has no effect on their subsequent capture probabilities (Otis et al. 1978). Both of these assumptions are almost impossible to control in field experiments due to animal behavior (i.e., dispersal, rutting behavior). The last assumptions are that animals do not lose their marks between sampling periods and no marks go unreported.
Methods exist for calculating population estimates for open populations where deaths, births, immigration, and emigration occur during the sample period (Seber 1982). The Cormack-Jolly-Seber method is one such method that calculates an estimate for open populations (Cormack 1964, Jolly 1965, Seber 1965). Like closed population estimators, the Cormack-Jolly-Seber method assumes constant and equal catchability. It also assumes all marked animals have the same probability of surviving and remaining in the population between sampling periods. A problem with open population estimators is that they tend to be less precise than closed population estimators (White et al. 1982) and are not robust to heterogeneity of individual capture probabilities (Pledger and Efford 1998). However, open population estimators can calculate other population parameters such as survival and reproductive rates. Kendell et al. (1995) developed a robust design model that combines both open and closed population estimators. A limitation of this model is the lack of incorporation of individual heterogeneity in the estimation of population size. Huggins (1991) developed a model that incorporates individual heterogeneity into the population estimate, but it still is less precise than closed population estimators. Otis et al. (1978) formulated a procedure for estimating population size that incorporates variability in probability of capture, due to time, behavioral responses, and heterogeneity among animals in a specified population; only one assumption exists: that a population was closed. Models were formulated for these estimators and incorporated into a computer program CAPTURE, which uses a model selection routine to determine the best estimator given the data. The selection routine uses between model tests, discriminate function analysis, and goodness-of-fit to rank the model estimators (White et al. 1982).
Traditionally, mark-recapture studies involve the actual capture and handling of animals, which possibly may affect the future capture probability of an individual. Increasingly, more studies have shown camera trapping is a feasible alternative to the traditional mark-recapture method. Remote photography sometimes is preferred over traditional methods because study animals simultaneously and continuously are detectable over a large area or among different habitats (Mace et al. 1994). A disadvantage is the use of bait to attract animals, because individuals react differently to bait (Cutler and Swan 1999). However, not all studies require bait to attract animals (Karanth and Nichols 1998). Mark-recapture methods assume individuals can be identified to determine whether they have been “captured” and “recaptured” (Silver et al. 2004). Camera trapping methods can be used successfully where individual male deer are identified by unique antler characteristics (Jacobson et al. 1997). Female and antlerless deer, which are defined as males having antlers not protruding through the skin (i.e., button bucks), can be identified if they are uniquely marked (e.g., eartags).

Population reconstruction

Another independent method to estimate deer densities for comparison is population reconstruction (Downing 1980), which is a population analysis technique that uses harvest-at-age data and backward addition of cohorts to estimate minimum population size over time. It has been employed recently to estimate deer densities using a modified approach (Davis et al. 2007) that allows for truncating of age classes within a software program. Because these data are collected routinely by state agencies, it is a highly appealing method for managers to estimate population densities. The state of Wisconsin has used this method, known as sex-age-kill method (Creed 1984), since the
early 1960’s. Population reconstruction works best with animals whose primary cause of
death is harvest mortality or where mortality can be estimated accurately. The problem is
that Downing’s (1980) 3 assumptions, that natural and total mortality rates are constant
over time, the oldest two age classes’ mortality rates are equal, and that age determination
is accurate, are hard to meet under real world conditions (Davis et al. 2007). Natural
mortality rates are not accounted for in population reconstruction as well. Depending on
how the age classes are truncated, a time lag exists for reconstruction estimates.

METHODS

Remote camera population density estimates

I deployed Deer Cam® (Park Falls, Wisconsin, USA) heat and motion sensing
remote cameras in a grid throughout the study area during the fall of 2003, 2004 and
2005. Because there is no information available on home range size for male deer in the
Piedmont region of Virginia, we assumed a Piedmont male deer’s home range most
closely resembled the range of coastal plain deer, which on average was 300 ha (C.R.
Ruth, South Carolina Department of Natural Resources Personal Communication),
Spacing cameras every 800 meters (400 m radius) provided at least 1 camera within each
buck’s home range. I used ARCVIEW© to space camera traps 800 m apart on Digital
Ortho Quads (USGS). In the field, I then used Global Positioning System units (GPS) to
determine exact field location for positioning of the cameras. At this spacing, 23 cameras
(1 camera per station) were required to systematically cover the Amelia Springs study
site (total area = 1,538 ha). Cameras were attached to trees at a height of 0.6 m, and
positioned 5.5 m away from the targeted capture area (Jacobson et al., 1997). Cameras
were placed along roads, trails, and game trails and were baited with corn during the non-
hunting season to obtain a clear picture of bucks with their heads down for antler identification. Each photograph was marked automatically with the date and time when triggered. I selected a 5-minute delay between pictures.

Cameras were operated during 2 separate intervals and each 24 hour day within a trapping interval was a distinct encounter occasion. Camera trapping for the first interval (non-hunting season) began in early September and ended in early October for a total trapping period of 30 trap days in 2004 and 2005, and 29 trap days in 2003. During the first period in 2003 and 2005, I baited camera sites with whole kernel corn. The second trapping interval (hunting season) ran from mid-October to mid-November and lasted 30 days except for 2005 when it ran 35 days. These intervals have been shown to have the least variability in buck:doe ratios (Koerth and Kroll 2000).

Bait was removed from all camera sites prior to the start of the second interval because it is not legal to hunt over bait in Virginia during the hunting season. I compared camera trap success between the 2 periods to assess if absence of bait decreased trap success; however, differences also may have been caused by seasonal effects. During each interval, cameras were checked every 7 days for proper functioning and to replace batteries, film, and bait if required. I identified individual antlered bucks from photographs using antler configuration (number of points, relative length of points, angle projection of points, and relative location of points on the antler beam), antler mass, pelage characteristics, and body traits (Jacobson et al. 1997) (Figure 3.1). I identified individual does (females) by colored numbered ear tags (i.e., either marked or un-marked). When identification of an animal was uncertain, the photograph was excluded.
from analysis. Verification of individuals in photographs was made by 2 independent
analysts.

I determined trapping success, the number of animal capture events per 100 trap
nights (TN), for each separate trapping interval and for every species captured on film.
This was calculated by summing the total number of trap nights for each interval (minus
any nights cameras were not functioning) and then dividing photographic capture events
(discounting the same animal repeatedly captured during each day/interval) of each
species, by the total number of trap nights multiplied by 100 to derive the individual
species’ trapping success per 100 TN.

I used Program CAPTURE to calculate 2 population estimates from remote
camera data, for antlered buck white-tailed deer, and for antlerless deer and female deer
combined. The model selection routine in program CAPTURE was used to select the
most appropriate model for estimation of population size for each dataset. The model
selected by CAPTURE produces the most likely population size estimate given the
structure of the data.

Estimating density requires an estimate of the total area surveyed (effective trap
area). Effective trap area was calculated by determining the maximum distance moved
between cameras by each individual deer. The maximum distance moved of all
identifiable deer was averaged to determine the mean maximum distance moved
(MMDM). I used half the MMDM number (½ MMDM) as the buffer radius around each
camera station and, after dissolving buffers, ARCGIS calculated total buffered area to
estimate an effective survey area. This methodology is consistent with other field camera
trapping surveys (Dice 1934; Wilson and Anderson 1985; Karanth and Nichols 1998,
Silver et al. 2004). Deer captured repeatedly at the same station do not have a maximum distance moved and were excluded from MMDM calculations. I combined MMDM for all 3 years to determine a single average MMDM value for the hunting versus non-hunting season. I then divided the population size estimates from the best model in program CAPTURE for each year, and averaged across years, by this effective area surveyed to determine density for each year, and across years, for the hunting and non-hunting seasons. Standard errors on density estimates were calculated following Nichols and Karanth (2002) method: 

\[ SE(D) = \frac{\sqrt{\text{var}(D)}}{\sqrt{N}}. \]

A one-way ANOVA was used to test for differences in maximum distances moved between periods 1 and 2 as well as among years. A 3-year average MMDM was calculated to determine effective trap area surveyed for each period.

Population reconstruction estimates

To estimate population size for male and female deer on Amelia Springs by a second method, I used Downing’s population reconstruction with the Davis et al. (2007) truncating modifications. Ages were truncated into 3 classes (0-1, 1-2, 2-3) allowing for fewer years of incomplete cohorts and the ability to overcome the inaccuracies of tooth wear and replacement in aging older deer.

Amelia County population estimates, used for comparisons, were determined using Downing population reconstruction, provided by Matt Knox, VDGIF deer program coordinator.

RESULTS

Trapping success
White-tailed deer had the highest trap success of all animals captured on Amelia Springs. Trapping success for white-tailed deer in intervals 1 (September) and 2 (Oct.-Nov.) during 2003-2005 was 22.2/100 TN and 19.4/100 TN, respectively. Crows (*Corvus brachyrhynchos*; 3.14/100 TN) and raccoons (*Procyon lotor*; 2.50/100 TN) constituted the bulk of other animal captures in interval 1, 2003-2005 and Eastern wild turkey (*Meleagris gallopavo*; 0.57/100 TN) and gray squirrel (*Sciurus carolinensis*; 0.56/100 TN) were most prevalent in interval 2, 2003-2005 (Fig. 3.4).

*Camera trapping estimates*

I reported the 2 top models (as chosen by the model selection routine in program CAPTURE) among the 3 chosen which were: M(o) constant probability of capture, M(h) variable probability of capture by animal (heterogeneous), and M(th) variable probability of capture based on time variation and individual heterogeneity (Table 3.1).

During the baited period, September (non-hunted) 2003, 28 individual bucks were captured by cameras 46 times; 44 individual bucks were captured 65 times during the unbaited period in October-November (hunted) 2003. Only 3 photos were excluded from analysis due to identification uncertainty. During 2003, interval 1 antlered male estimated abundance from program CAPTURE ranged from 40-55, whereas interval 2 antlered male estimates ranged from 77-100 (Table 3.1).

During September 2004 (non-hunted; period 1), 29 antlered deer were captured, 38 times; 4 photos were excluded from analysis due to identification uncertainty. In October-November 2004 (hunted; period 2), 64 antlered bucks were captured 96 times; 7 photos were excluded from analysis due to identification uncertainty.
estimates from CAPTURE for antlered male deer for periods 1 and 2 ranged from 67-228 and 109-284, respectively (Table 3.1).

In September 2005, 36 individual male deer were captured 62 times during period 1 (non-hunted; baited); 4 bucks were excluded from analysis due to identification uncertainty. Seventy-four individual male deer were captured 116 times in period 2 (hunted; un-baited); 15 photos were excluded due to identification uncertainty. Population estimates ranged from 53-75 for the baited interval and 119-182 for the un-baited interval.

Capture results, probability of capture, closure tests, area surveyed, density estimates, and standard errors are summarized in Table 3.1

There were no differences in maximum distances moved among years for the 2nd period ($F_{2,27} = 1.36, P = 0.275$), and period 1 maximum distances moved had insufficient data for analysis, but had a low mean and standard error ($\bar{x} = 817$m, S.E. = 36.9) for the three years surveyed. I therefore combined data for each trap interval and determined a 3-year average for each interval (2003-05). Using the $\frac{1}{2}$ MMDM buffer radius surrounding each camera station, the area surveyed for the September (non-hunted) trapping interval was 11.9 km$^2$ (Figure 3.2). The buffer radius for the October-November (hunted) trapping interval resulted in a total area surveyed of 37.7 km$^2$ (Figure 3.3).

*Trap Interval 1 densities*

In trapping period 1 (non-hunting season), program CAPTURE (best model) estimated 40, 67, and 75 antlered male deer in 2003, 2004, and 2005 respectively. Area surveyed for interval 1 was 11.9 km$^2$, thus densities were 3.3, 5.6 and 6.3/km$^2$,
respectively (Table 3.1). I did not recapture enough females in period 1 for any year to calculate a population estimate.

*Trap Interval 2 densities*

In trapping period 2 (hunting season), program CAPTURE (best model) estimated 77, 284, and 182 antlered male deer in 2003, 2004, and 2005 respectively. Area surveyed for interval 2 was 37.7 km\(^2\) thus densities were 2.0, 7.5 and 4.8/km\(^2\), respectively (Table 3.1). I did not recapture enough females in period 2 for any year to calculate a population estimate.

*Population reconstruction estimates*

All estimates are Downing method reconstructions unless otherwise noted. Minimum population estimates for the Amelia Springs study site (Table 3.2) for the most recent truncated year (2003) were 52 male and 98 female deer; this produced a minimum buck:doe sex ratio of 1:1.8. VDGIF’s Amelia County minimum population estimates for 2003 were 3,847 male and 12,863 female deer for a minimum buck:doe sex ratio of 1:3.3 (Table 3.2). VDGIF Amelia County estimates for 2004 and 2005 were 3,738 males and 9,229 females (1M:2.5F) and 3,629 males and 8,619 females (1M:2.4F), respectively. The equivalent male and female densities were: 4.3/km\(^2\) and 14.4/km\(^2\) in 2003, 4.2/km\(^2\) and 10.3/km\(^2\) in 2004, and 4.1/km\(^2\) and 9.6/km\(^2\) for 2005.

**DISCUSSION**

Reliable estimates of population sizes often are difficult to obtain and require an immense amount of effort in the field. Techniques used to calculate population estimates from field data often are unreliable and subject to a number of different assumptions. For instance, McCullough and Hirth (1988) found bias exists in Lincoln-Peterson estimates.
due to violation of the equal catchability assumption, and Otis et al. (1978) noted problems with program CAPTURE when sample size and recapture rates are low, capture probabilities are low and when closure was violated. In addition, antlered males may be more susceptible to camera capture during the rutting season (October-November) when they are seeking females. Conversely, females may be more readily camera captured during the September period when bait was used.

Assumption violations

The most critical assumptions for getting precise and unbiased estimates from closed populations are demographic and geographic closure (White et al. 1982). In this study, the only interval that appeared to violate the closure assumption (CAPTURE closure test) was the first interval (September) in 2005. However, there are reasons to believe that the population was closed during this time period. Koerth and Kroll (2000) reported that camera trapping sex ratios in Texas had the lowest coefficient of variation in October of all months. Koerth et al. (1997) reported that October camera surveys in Texas provided sex and age ratio comparable to aerial surveys. A noticeable dip in fawn:doe ratios, higher buck:doe ratios, and consequently higher coefficients of variance, occurred during the rut (December) and general hunting season according to Koerth and Kroll (2000). The rut, which generates the most variability, occurs a month earlier in Virginia than in Texas, leading me to believe that the comparable month with lowest variability would be September. Data from this study indicated that yearling males moved out of the population during the first two weeks of October, suggesting that neighboring yearlings moved into the population in October. Hunting season (which began in October on Amelia Springs) is known to alter the movements of deer (Van Etten et al. 1965, Sparrowe and Springer 1970, Kammermeyer and Marchinton 1976, Root et
al. 1988, VerCauteren and Hygnstrom 1998, Kilpatrick and Lima 1999). Natural mortality in this population from this study was 0.15%. Clearly, the stability of sex ratios is important to maintain proper management controls (i.e., harvest levels) on a QDM area and I believe, based on the aforementioned reasons, the September trapping interval was a time of no immigration/emigration, no births, and very little natural mortality therefore, I believe the estimates for the first trapping periods (September 2003-2005) likely are the most reliable in terms of true population density.

Program CAPTURE closure test is described by Rexstad and Burnham (1991) as not being robust. Additionally, CAPTURE has been shown to lack power, especially when sample size and capture probabilities are low (Mowat and Strobeck 2000). Model selection plays an important role in statistical inference and the model selection procedure in CAPTURE can be unreliable and, in some circumstances, subject to choosing an inappropriate model (Chao 2001).

With the above caveats noted, mark re-capture density estimation techniques are based on mark-recapture theory and have rigorous, repeatable estimation procedures that have a long history in wildlife sciences. They produce estimates with precision well described by standard errors and confidence intervals. Additionally, camera mark-recapture study designs currently are undergoing scrutiny across numerous species to standardize the technique and make results comparable across study sites. Lastly, the cameras themselves are not thought to introduce observer bias in data collection methods, eliminating a potential source of sampling error.
Population Densities/estimates

The average number of male deer (camera estimates) on Amelia Springs during 2003-2005 was 60 or 5.0 per km²; the average in Amelia County was 4.1 km². Female deer (population reconstruction) on Amelia Springs averaged 11.4 per km². Johnson et al. (2004) reported one deer per 5.1 ha or 19.6 per km², on the fenced Milan Army Ammunition Plant, Tennessee, during the fall and Jacobson et al. (1997), in Mississippi, reported one deer per 6.9 ha or 14.3 per km². Both studies used similar camera trapping methods but did not use MMDM or program capture techniques to estimate density. To my knowledge, my study is the first to apply remote camera techniques developed for other species on white-tailed deer. This technique holds great promise for deer population monitoring in the future. It is effective, relatively inexpensive, and follows rigorous, well-developed, population size estimation methods.

Male and female population reconstruction minimum population estimates for the most recent available year of 2003 on the Amelia Springs study site resulted in a buck:doe ratio of 1:1.8. A sex ratio under 1:2 is characteristic of trophy management programs (Brothers and Ray 1982), whereas a properly managed deer herd under QDM should have a sex ratio of 1:2-3 (Adams 1985). Amelia county minimum population estimates using population reconstruction resulted in a 1:3.3 buck:doe ratio, a ratio indicative of a maximum productivity harvest program (Wilson and McMasters 1974). Minimum population estimates do not take into account natural or hunting mortality rates and are a minimum count of the number of animals in the population at harvest. The number is derived by back counting animals; a deer harvested at 3.5 years old was in the population at 2.5 and 1.5 etc., this produces a minimum population estimate, actual
population densities are likely higher. Based on these data it appears buck:doe ratios on Amelia Springs hunt club may be trending toward ratios prescribed by QDM.

Conclusions

For period 1 (non-hunting), the spacing of cameras (Figure 3.2, using a 408.5m radius) left areas not covered by a camera (e.g., holes in the grid) and could have led to undercounting of animals during the September period. We had no prior knowledge of Piedmont deer home range size so this was our best estimation of what the grid spacing should be. Although I believe our spacing was correct, this effect could have led to underestimates of deer density on the hunt club if camera spacing was too far apart. Interval 1 (non-hunting) estimates, from camera trapping, were during a period of relative population stability (no emigration/immigration or rutting activity) and thus are believed to be valid. Interval 2 (hunting season) estimates, from camera trapping, were 1.5-2.0 times larger than interval 1 (non-hunting season) estimates. I believe this was due to known instability in the population due to rutting activity and juvenile dispersal. Population reconstruction estimates, derived from hunter harvest data, were similar to interval 1 (non-hunting) estimates. The mark recapture technique is more robust than population reconstruction estimates, which are minimum estimates.

Based on the variable factors discussed here, I believe that camera mark recapture density estimates are closest to the true population size for this study. Determination of the most accurate estimates must use all information pooled together, including knowledge of the animal population being studied, results from other studies, goodness of fit tests in computer programs like CAPTURE, and examination of the raw data structure. The degree of accuracy necessary depends on the desired objective to be
met from a population estimation study. In this case, I believe the estimates are accurate enough to allow for stricter control of the deer population on Amelia Springs to maximize quality deer management. Having reliable population estimates allows the manager to set yearly harvest quotas for males and females that should improve male quality (antler and weight) through older age structure, lower the age structure of females, and improve the overall quality of deer in the population in relation to the habitat, all hallmarks of quality deer management. Although mark recapture studies can be variable and subject to open interpretation, they are still the best tools to make informed decisions regarding wildlife populations.
Table 3.1. Population and density estimates, closure tests and capture probabilities from program CAPTURE for Amelia Springs Hunt Club, Jetersville, Virginia for fall 2003-05. Model selection routine (criteria value) in CAPTURE was used for model selection. Densities based on mean maximum distance moved (MMDM) between camera stations and effective survey area.

<table>
<thead>
<tr>
<th>Year/Interval</th>
<th>Caps.</th>
<th>Recaps.</th>
<th>Photos omitted</th>
<th>Cap. prob.</th>
<th>Closure test p-value</th>
<th>Z-Score</th>
<th>Model (ranked order)</th>
<th>Model selection criteria</th>
<th>Pop. Est. (S.E.)</th>
<th>95% CI range</th>
<th>Effective survey area km²</th>
<th>½ MMDM density bucks/km²</th>
<th>Density per km² (S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003 (1)</td>
<td>28</td>
<td>18</td>
<td>0</td>
<td>0.09</td>
<td>0.11</td>
<td>-1.19</td>
<td>M(o)</td>
<td>1.0</td>
<td>40 (7.5)</td>
<td>32-63</td>
<td>11.9</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M(h)</td>
<td>0.75</td>
<td>55 (13.1)</td>
<td>39-93</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004 (1) Non-hunted</td>
<td>29</td>
<td>9</td>
<td>4</td>
<td>0.05</td>
<td>0.86</td>
<td>1.08</td>
<td>M(o)</td>
<td>1.0</td>
<td>67 (20.3)</td>
<td>43-130</td>
<td>11.9</td>
<td>5.6</td>
<td>4.9(0.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M(h)</td>
<td>0.85</td>
<td>112 (20.5)</td>
<td>81-163</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005 (1)</td>
<td>36</td>
<td>26</td>
<td>4</td>
<td>0.10</td>
<td>0.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-2.91</td>
<td>M(th)</td>
<td>1.0</td>
<td>53 (7.8)</td>
<td>44-76</td>
<td>11.9</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M(o)</td>
<td>0.09</td>
<td>75 (20.3)</td>
<td>52-138</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003 (2)</td>
<td>44</td>
<td>21</td>
<td>3</td>
<td>0.05</td>
<td>0.24</td>
<td>-0.68</td>
<td>M(o)</td>
<td>1.0</td>
<td>77 (12.8)</td>
<td>60-112</td>
<td>37.7</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M(h)</td>
<td>0.78</td>
<td>100 (20.7)</td>
<td>73-157</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004 (2) Hunted</td>
<td>64</td>
<td>32</td>
<td>7</td>
<td>0.05</td>
<td>0.11</td>
<td>-1.18</td>
<td>M(o)</td>
<td>1.0</td>
<td>109 (14.7)</td>
<td>89-147</td>
<td>37.7</td>
<td>7.5</td>
<td>4.8(1.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M(h)</td>
<td>0.88</td>
<td>284 (36.7)</td>
<td>223-368</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005 (2)</td>
<td>74</td>
<td>42</td>
<td>15</td>
<td>0.06</td>
<td>0.23</td>
<td>-0.72</td>
<td>M(h)</td>
<td>1.0</td>
<td>119 (13.8)</td>
<td>100-155</td>
<td>37.7</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M(o)</td>
<td>0.98</td>
<td>182 (31.2)</td>
<td>137-262</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Open population  
<sup>b</sup> Density estimate and SE derived from 3 year average of population estimates
Table 3.2. Minimum density estimates (per km²) from population reconstruction for Amelia Springs Hunt Club and Amelia County (provided by VDGIF), Virginia, for fall 2003.

<table>
<thead>
<tr>
<th>Year</th>
<th>Amelia Springs M</th>
<th>Amelia Springs F</th>
<th>Sex Ratio (buck:doe)</th>
<th>Amelia County M</th>
<th>Amelia County F</th>
<th>Sex Ratio (buck:doe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>3.4*</td>
<td>6.3*</td>
<td>1:1.8</td>
<td>4.3</td>
<td>14.4</td>
<td>1:3.3</td>
</tr>
<tr>
<td>2004</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>4.2</td>
<td>10.3</td>
<td>1:2.5</td>
</tr>
<tr>
<td>2005</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>4.1</td>
<td>9.6</td>
<td>1:2.4</td>
</tr>
</tbody>
</table>

*2003 most recent year available
Figure 3.1. Examples of how white-tailed deer are identified by unique antler characteristics, Amelia Springs hunt club, Amelia County, Virginia 2003-2005. Deer depicted in each series (e.g., A1-A2) are the same animal.
Figure 3.2. Total surveyed area using September MMDM buffer diameter of 817m, Amelia Springs Hunt Club, Amelia County, Virginia, 2003-05.
Figure 3.3. Total survey area using October-November MMDM buffer size of 1,444m, Amelia Springs Hunt Club, Amelia County, Virginia, 2003-05.
Figure 3.4. Animal camera capture rates (per 100 trap nights) for trapping periods 1 (September) & 2 (October-November), Amelia Springs hunt club, Amelia County, Virginia, 2003-2005.
Chapter 4. Amelia Springs hunt club harvest information compared to other DMAP managed hunt clubs in Amelia County

INTRODUCTION

Use of harvest data in population management

A quality deer management (QDM) program is only as effective as the quality of data collected (Hamilton et al. 1995). An understanding of the age structure, and its effects, on the herd is important in making management decisions. Severinghaus (1949) was the first to report that white-tailed deer could be aged with reasonable accuracy by tooth wear and replacement. This technique has become the most common method employed to age deer. A herd composed of primarily young animals indicates either a growing deer population or a heavy harvest. A very old age structure most likely indicates an inadequate harvest. Harvest management decisions for QDM, in most situations, can be made using three age categories: fawn, yearling, and 2.5 + years (Hamilton et al. 1995).

The Virginia Department of Game and Inland Fisheries (VDGIF) instituted a Deer Management Assistance Program (DMAP) in 1988. DMAP is a site-specific deer management program that increases a landowner’s or hunt club’s management options by allowing a more liberal harvest of antlerless deer. The primary goal of DMAP is to allow landowners and hunt clubs to manage deer herds locally and simultaneously increase VDGIF’s biological database and improve communication among landowners, hunt clubs, and the department (VDGIF 1999). Data collected by cooperators include: jaw bone for aging, beam circumference, number of points, weight, greatest inside spread, sex, presence/absence of lactation, and presence/absence of sloughing hooves.
The use and efficacy of selective harvest criteria to protect yearling male deer in hunted populations has been reported (Bullock et al. 1995, Demarias 1998). Shea and Vanderhoof (1999) in Florida, and Strickland et al. (2001) in Mississippi, reported that mean antler size of 2.5-year old harvested white-tailed bucks decreased because of selectively harvesting large-antlered 1.5-year old males and protecting small-antlered 1.5-year old males. Selective harvest criteria effectively can protect young males from harvest and increase the average antler size of harvested deer. Deer herd managers have relied on physical condition measures to assess population condition and formulate management recommendations (Johnson 1937, Guynn et al. 1988, Keyser et al. 2005). Ditchkoff et al. (1997) found that QDM at McAlester Army Ammunition plant, Oklahoma, was successful as illustrated by increases in body mass and antler characteristics of harvested deer. Similar results were reported by Adams (1985) and Cook and Fuchs (1989) for white-tailed deer in Texas.

METHODS

Hunter harvest information comparisons

I used harvest data collected through the VDGIF’s DMAP for comparison with harvest data from Amelia Springs hunt club. Dressed body weight (eviscerated), antler beam circumference, number of points, and inside spread, by age, of male deer harvested on Amelia Springs hunt club were compared to similar data from other hunt clubs practicing QDM, as well as clubs not practicing QDM, to aid in evaluating the effectiveness of QDM. Overall quality of male deer was defined by all metrics of measurement by age class. All clubs selected for analysis were located within Amelia County. I chose to compare adult male deer ≥2.5 years of age because QDM stresses
harvest of older animals and protection of yearlings. All female deer harvested, regardless of age, were included in the analysis. The analysis included 13 years of DMAP data (1992-2005) from 21 hunt clubs in Amelia County, which were compared to Amelia Springs hunt club data for the same period.

RESULTS

The Amelia County hunt club data, which included 21 different clubs participating in DMAP, totaled 3,130 (1,454M:1,676F) harvest records of deer. The average hunt club contributed 5.4 years of harvest information; 5 clubs contributed more than 10 years of harvest information. The Amelia Springs hunt club data contained 13 years of harvest records totaling 367 (125M:242F) deer.

Male deer >2.5 years harvested (Table 4.1) on Amelia County hunt clubs (n=417, \( \bar{x} = 2.2, \text{S.E.}=0.03 \)) were younger (\( p=0.006, t=-2.76, \text{df}=507 \)) than male deer (n=92, \( \bar{x} = 2.4, \text{S.E.}=0.07 \)) harvested on Amelia Springs. Average age of all aged male deer harvested on Amelia County hunt clubs was 1.0 year (n = 1514, S.E. = 0.02) and 1.9 for all aged male deer (n = 122, S.E. = 0.11) harvested on Amelia Springs. The average age at harvest for female deer (Table 4.1) on Amelia County hunt clubs (\( \bar{x} = 1.5 \text{ years}, n = 1,676, \text{S.E.} = 0.03 \)), and Amelia Springs hunt club (\( \bar{x} = 1.7, n = 241, \text{S.E.} = 0.08 \)) were not different (\( p = 0.08, t = -1.71, \text{df} = 351 \)).

Male antler characteristics

Antler diameter of males ≥2.5 years (Table 4.2) harvested on Amelia County hunt clubs was less than (\( p = 0.000, t = -7.30, \text{df} = 481 \)) the average diameter for ≥2.5 year old males harvested on Amelia Springs hunt club. The average number of antler points (Table 4.2) for males ≥2.5 years of age and harvested on countywide hunt clubs was less
than \( (p = 0.001, t = -3.37, \text{df} = 497) \) the number of antler points on deer harvested on Amelia Springs hunt club. In addition, the outside spread of antlers for males \( \geq 2 \) years of age (Table 4.2) harvested on Amelia County hunt clubs was less than \( (p = 0.000, t = -4.52, \text{df} = 271) \) outside spreads of deer harvested on Amelia Springs.

**Dressed body weights**

The average dressed body weight for all age male deer (Table 4.1) harvested on Amelia County hunt clubs was less than \( (p = 0.000, t = -9.56, \text{df} = 1138) \) the average weight of deer harvested on Amelia Springs hunt club. Average dressed weights for males greater than 2 years of age (Table 4.2) harvested on Amelia County hunt clubs was less than \( (p = 0.000, t = -5.81, \text{df} = 327) \) the average weight for deer harvested on Amelia Springs hunt club.

The average weight of all aged females (Table 4.1) harvested on Amelia County hunt clubs was less than \( (p = 0.000, t = -6.43, \text{df} = 1456) \) the average weight of females harvested on Amelia Springs hunt club.

**DISCUSSION**

The hallmark of a successful QDM program is increasing the age structure of bucks in the population (Brothers and Ray 1982, Hamilton et al. 1995). Increases in average body weights and antler sizes are also by-products of a successfully managed QDM deer herd (Adams 1985, Cook and Fuchs 1989, Jacobson 1992, Ditchkoff et al. 1997). QDM returns the herd to a more natural density and social balance (Hamilton et al. 1995). The ability to accurately age a deer is paramount in the implementation of proper management regimen. Without professional assistance, hunt clubs practicing QDM may make incorrect decisions in the management of their population. In this case,
the availability of DMAP made comparisons possible due to the required record keeping and technical assistance provided by the VDGIF district biologist. Unfortunately, there was not a local club that practiced true QDM, with which to compare Amelia Springs. The 13 years of data from Amelia County clubs likely provided an accurate picture of “normally hunted” clubs (i.e., clubs that harvest all legal males and a variable portion of does, but not at the intense female harvest level required for QDM).

**Age at harvest**

The average age structure of males harvested on Amelia Springs hunt club was older than the average age of males harvested on other hunt clubs in Amelia County which likely indicates a shift in the age structure. This fits with the basic QDM model first outlined by Brothers and Ray (1982) who suggested that the buck was the most desirable unit of a deer herd and efforts should be made to maximize the number available for harvest by protecting young males and reducing female numbers. Smith et al. (1983) concluded that a deer herd’s age structure is the single most important variable in determining average antler size; as males get older; their antlers increase relative to body weight. The apparent increase in average age of male deer on Amelia Springs hunt club has resulted in older and larger bucks being harvested there relative to nearby hunt clubs that do not practice QDM, as predicted by Smith et al (1983).

The female average age on Amelia Springs (1.7 years), which was similar to the county club average (1.5 years), also follows the QDM model. The female average age should remain low due to the continued intensive harvest over time of all age classes, which should reach a point where the majority of females harvested are those just recruited into the population. On Amelia Springs 78% of all females harvested were ≤2.5
years of age. McCullough (1979) and Brothers and Ray (1982) reported that an increase in antlerless deer harvest lead to higher reproduction and recruitment in deer populations (density dependent growth). In East Texas, Fleming (1983) reported increased reproduction resulted in a 15% increase in population size on a hunt club practicing QDM despite intensive harvest of females. Although reproductive information is not available for Amelia Springs, it is conceivable that the increase in harvest there elevated the rate of reproduction and consequently the density. White and Bartman (1997) reported that, in deer populations with large year-to-year variation, detection of density dependence without a spatial control for temporal variation was unlikely. According to Keyser et al. (2005), density and physical parameters on marginal ranges have not been linked in some studies (Osborne et al. 1992, Shea et al. 1992), leading many biologists to conclude that some habitats are simply too poor for density-dependent responses to either be detected or to occur (Shea and Osbourne 1995).

*Male antler characteristics*

Antlers are the ultimate driving force behind hunt club participation in QDM. Antler quality is driven by 3 factors: nutrition, age, and genetics (Kroll 1994). Age and level of nutrition have long been considered the 2 major independent factors governing antler development (Severinghaus et al. 1950, Brohn and Robb 1955, Dahlberg and Guettinger 1956, French et al. 1956, Severinghaus and Cheatum 1956, DeGarmo and Gill 1958, Ryel and Fay 1962). Clearly, because antlers are made up of annually generated bone, the dietary factors that are vital for bone (antler production) development are of great importance. These factors include energy, protein, calcium, phosphorus, and vitamins A and D (Ullrey 1983). Energy for antler production is reflected by the health of
the deer. Antler sizes of yearling bucks in Michigan were determined by the physical condition of the deer (Burgoyne et al. 1981). The organic matrix of preossus antlers is almost entirely protein and it has been determined that the timing of protein availability in relation to antlerogenesis is important for normal antler development (Ullrey 1983). Kroll (1994) suggested a diet that contains at least 16% protein for maximum antler development. Calcium requirements for normal antler development were found to be 0.45%, phosphorus levels 0.30%, and vitamin A and D levels undefined (Ullrey 1983). French et al. (1956) found no increase in antler size when vitamin A and D supplements were given.

Genetics is the last factor determining antler growth. Harmel (1983) found that antler size and body weights can be influenced greatly by genetics; his research showed that individuals with poor antler traits will produce poor antlers no matter the quality of food consumed by the animal. To improve a deer herd’s genetics, either the deer with superior traits or his semen would have to be introduced into a population. The practice of genetic manipulation is hampered by regulations prohibiting interstate transport of live deer. The cost of capturing wild females and impregnating them with semen from genetically superior bucks at a level great enough to make a difference is impractical. Also, sufficient nutrition to maximize antler production is lacking across many ranges (Kroll 1994), thereby masking any superior antler genetics and making management of genetic structure in a herd near impossible. In this case, Amelia Springs has tried to improve two of the three factors affecting antler growth, nutrition and age. Amelia Springs hunt club members have planted supplemental food plots since inception, and increased the age structure of males on the hunt club. Body growth takes precedence over
antler growth during the first 18 months of life; nutritional intake in excess of base body requirements then goes to antler production (French et al 1956, Brothers and Ray 1982, Clutton-Brock et al 1982). Increased antler size (diameter, points, outside spread) at harvest on Amelia Springs is due in part to selective harvest of males ≥ 2 years of age. Deer that reach the second year of life begin to show antlers of quality size (Brothers and Ray 1982, Kroll 1994, Sauer 1994). Queal (1968), found that beam diameter and beam length had the strongest correlation with antler volume, number of antler points were also a strong correlate. Amelia Spring’s bucks also are larger in antler size because of an increase in age structure, meaning more bucks of a quality size are available for harvest. Prior to 2004, a quality buck on Amelia Springs was defined as a buck with at least 16 inches of antler beam length. After 2004, it was increased to 18 inches. Based on the data from Amelia Springs, 2 of 3 factors involved in antler production have improved, resulting in better quality deer than other hunt clubs in the county.

*Dressed weight at harvest*

Dressed weights for male deer on Amelia Spring hunt club were significantly higher (11.2 kg) than those harvested on other Amelia County hunt clubs. Selective harvest of the largest males by hunters apparently resulted in higher weights because older bucks almost always, barring individual health problems, weigh more than younger bucks. Males reach mature body weights at 5 years of age (Jacobson 1995), so theoretically, the closer the average age at harvest is to full maturity the larger the buck would be. The average age at harvest data supports this result because Amelia Springs’ bucks were older at harvest than county bucks. Second, QDM led to a reduction in the
density of female deer, leaving more available food within the habitat for bucks (Brothers and Ray 1982).

Female dressed weights on Amelia Springs were higher by 3.4 kg than females harvested by Amelia County hunt clubs. I believe that the QDM program used on Amelia Springs produced an increase in body weights due to a reduction in the density of females. Weights of Amelia Springs females were higher at the same average age at harvest than the rest of Amelia County hunt clubs on what appeared to be lower overall quality habitat. However, I have no habitat data to back up my assessment of habitat quality. Because females do not have antlers to put energy into, females reach mature body weights at 4 years of age and reach a higher percentage of their mature weight in their first year of growth (Jacobson 1995). I believe that the weights of females on Amelia Springs were higher despite the marginal habitat because female densities were low and does were getting a larger “share” of the available food supply negating the marginal habitat effect.
Table 4.1. Average age and dressed weights (\( \bar{x} ; \) S.E.) at harvest for all aged white-tailed deer harvested on Amelia Springs and Amelia County hunt clubs, Virginia, 1992-2005.

<table>
<thead>
<tr>
<th>Location</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Age(yr)</td>
</tr>
<tr>
<td>Amelia Springs</td>
<td>122</td>
<td>1.9(0.11)</td>
</tr>
<tr>
<td>Amelia County</td>
<td>1454</td>
<td>1.0(0.02)</td>
</tr>
</tbody>
</table>
Table 4.2. Average vital statistics ($\bar{x}$; S.E.) of 2+ year old male white-tailed deer harvested on Amelia Springs hunt club in Amelia County, Virginia, 1992-2005.

<table>
<thead>
<tr>
<th>Metric</th>
<th>N</th>
<th>Amelia Springs hunt club</th>
<th>N</th>
<th>Amelia County hunt clubs</th>
<th>t-stat</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of points</td>
<td>89</td>
<td>7.9(0.15)</td>
<td>410</td>
<td>7.2(0.09)</td>
<td>-3.37</td>
<td>0.001</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>92</td>
<td>2.4(0.07)</td>
<td>417</td>
<td>2.2(0.03)</td>
<td>-2.76</td>
<td>0.006</td>
</tr>
<tr>
<td>Antler diameter (mm)</td>
<td>88</td>
<td>32.6(0.55)</td>
<td>394</td>
<td>26.9(0.33)</td>
<td>-7.30</td>
<td>0.000</td>
</tr>
<tr>
<td>Dressed weight (kg)</td>
<td>92</td>
<td>53.3(0.77)</td>
<td>237</td>
<td>47.8(0.48)</td>
<td>-5.81</td>
<td>0.000</td>
</tr>
<tr>
<td>Outside spread (cm)</td>
<td>50</td>
<td>44.7(0.68)</td>
<td>223</td>
<td>39.8(0.45)</td>
<td>-4.52</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Conclusions and Management Recommendations

Quality Deer Management on Amelia Springs hunt club

Based on the results of this study, Quality Deer Management (QDM) on Amelia Springs hunt club is relatively effective. The club’s goals to have a more balanced sex ratio, older “shooter” bucks, and larger bodied animals all apparently are being met. Body and antler sizes are larger than other Amelia county hunt clubs, the age structure has shifted to older age animals based on harvest data, and the buck:doe sex ratio, based on the best available information, is around 1:2. Other evidence to support my claim that QDM is effective on Amelia Springs is in the form of photo data indicating considerable numbers (6-8 annually) of older large males (Figure 5.1) on the property that are never seen by hunters. The latter is not unexpected. Van Etten et al. (1965) reported that hunters spent an average of 18 hours to sight a buck in a 1-mile hunting enclosure. Additional photographic evidence exists of bucks that have surpassed their prime and whose antlers have degraded (see the large 4-point and 3-point bucks pictured in Figure 5.2).

The expectation of some hunters on Amelia Springs hunt club that every buck left this year will be larger and available for harvest the following year (i.e. stockpiling) is unrealistic. This does not happen to the degree that most hunters believe. Removal of the dam through hunting can help retain some of the young bucks that would be driven off by their mothers, but, for all studies I reviewed, it does not stop emigration of all males. For this study, I documented a 46% emigration rate of juveniles. A decrease in female harvest (dam removal) likely would raise this rate, although I expect not dramatically. Deer also suffer from non-hunting mortality (natural) at a rate as high as 25% (Dusek et al. 1989, Fuller 1990, Nixon et al. 1991); poaching, parasitism, automobile collisions, disease, and
malnutrition all take their toll. I observed natural mortality of 15% on Amelia Springs among radio-tagged male deer. Natural mortality is high for fawns and old deer, but low in other age classes (Jacobson and Guynn 1995). The end result is that every buck produced by a local population cannot be stockpiled.

Another expectation is that every buck passed up on harvest will develop into a trophy buck. Some Amelia Springs hunters confuse trophy and quality. Quality is represented by the best that a herd in a given area can achieve (Van Brackle and McDonald 1995). Here, I believe, some hunt club members’ expectations are greater than the results possible. As stated earlier, age, nutrition, and genetics influence the quality of deer on an area. Young bucks are being passed up by hunt club members, which is the most important factor for QDM. Nutrition on Amelia Springs hunt club is something that can be improved upon and genetics are rarely a limitation anywhere (Harmel 1983).

In Virginia, the top end for most free ranging bucks should be a 3.5 year old with antlers of 130-140 inches (Boone and Crockett score) and 2.5 year old deer with antlers averaging around 110 inches (Knox 2006). For Amelia Springs, over the course of 13 years, one 130-140 inch buck was killed annually (W.D. Quaiff, Amelia Springs Hunt Club, personal communication), the rest averaged 110-120 inches. These sizes confirm that quality deer are being harvested consistently on Amelia Springs given the current nutritional quality of the area.

It should be noted that this study was a base assessment of QDM. There were not enough years of data from this study to draw any strong conclusions about QDM efficacy. Further studies should be undertaken to validate my results and the effectiveness of QDM on a landscape scale.
Management Recommendations

Habitat option one

The most viable option to improve deer management on Amelia Springs hunt club would be to improve overall habitat quality. Piedmont habitats are made up of sandy loams and red clay subsoils that generally are acidic and low in organic matter, phosphorous, and nitrogen— in layman’s terms, poor. Forage quality and quantity may have the greatest impact on QDM (Shea and Osbourne 1995).

Brown (2007) suggests that a deer’s protein needs are generally met by the habitat without the need for supplemental feeding and that energy is a more limiting factor in the diet due deer avoidance of predators, browsing, lactation, body and antler growth, pregnancy, and fighting, which increase energy needs above a normal day’s energy requirement. A well managed habitat, which fulfills the needs of water, food, space and cover, will help the herd to reach its genetic potential for body and antler size without supplemental feeding (Brown 2007), but a properly managed deer habitat will not appear overnight, it will require years of manipulation and management for maximum success.

Management of fields currently in food plots on Amelia Springs could be altered to promote not only food, but cover through the use of early succession habitat. Approximately 70% of a deer’s spring and summer diet is forbs (Gruchy and Harper 2007). Forbs are broadleaf deciduous plants such as pokeweed (*Phytolacca americana*), beggar’s lice (*Desmodium spp.*), ragweed (*Ambrosia artemisiifolia*), and goldenrod (*Solidago spp.*) to name a few. Unlike food plots, these plants have minimal costs associated with producing them during the growing season since they come up naturally. Native forbs nutritionally rival many plants common in food plots (Gruchy and Harper...
2007) and provide cover throughout the year; another component common in early succession habitats are shrubs like blackberry (*Rubus* spp.), sumac (*Rhus* spp.), and wild plum (*Prunus Americana*). All of these shrubs provide food and cover for deer during various times of the year. Management of this habitat type is easy and far less intensive than food plot management. The fields should be placed on a rotational disking or burning schedule of 2-3 years. A 3-year rotation would maximize the amount of shrubs within the field while a 2-year rotation would maximize forb production. Either rotation is beneficial and desirable for food and cover for deer as well as a myriad of other species. Disking should be done during late winter-early spring to encourage native forbs and should be done in strips to allow for some cover and food to be left. Strips should be alternatively disked in subsequent years. Prescribed fire should be conducted during the same time frame, whole fields burned if less than 2-3 acres and larger fields divided into smaller equal blocks for effective management.

Thinning and burning of pine stands, which are prevalent on Amelia Springs, could be managed to promote more sunlight into the understory, which promotes forb and grass cover similar to early succession habitat and which have similar benefits of increased food and cover. A crop tree release program targeting mast producing species beneficial to deer could be undertaken. Additionally, targeted fertilization of the best producing oak trees (*Quercus spp.*) together with release, may improve browse and acorn yield. Wolgast (1978) found significant increases in acorn production and browse in bear oak (*Quercus ilicifolia*) when treated with fertilizer in New Jersey.

In Maine, Abell and Gilbert (1974) reported increases in available browse on fertilized clear cuts. Rate and type of fertilization on Amelia Springs should be
determined by soil test and through consultation with the local Virginia cooperative extension agent, but generally speaking applications should be on the best mast producing trees and clear cuts. An overall timber management plan for wildlife should be developed in consultation with a certified forester with emphasis on browse and mast improvement.

Habitat improvements previously mentioned may be eligible for 50-75% cost share from the Natural Resource Conservation Service (NRCS) through programs like Wildlife Habitat Improvement Program (WHIP) or Conservation Reserve Program (CRP). The drawback to the habitat improvement option is that the managing entity has to have long term control over the property since habitat management is a multi-year process. Additionally, most cost share programs require ownership of the property for qualification, with the exception of WHIP. In the case of Amelia Springs, portions of this option (thinning, CRP) may not be viable as the club is owned by multiple landowners with varying management views.

Habitat option two

This management option is more conducive to hunt clubs, who lease land from year to year, and want to immediately feel that they can affect a change in the deer herd health. It is important to note that food plots are beneficial to individual animals, but not whole populations. On Amelia Springs, food plots are planted annually on 20-30 acres (0.5% of total acreage) with a “bring the deer to the gun” attitude, whereby only a small percentage of the property is planted to concentrate deer. This method is useful because it may enable hunters to more effectively manage harvest of females. Corn has been the crop most often planted for deer, but corn has disadvantages: it has high fertility
requirements, provides little protein to bucks growing antlers during the summer, and leads to topsoil loss from erosion due to the lack of groundcover (Ball et al. 2002). Additionally, feeding deer corn is like feeding candy to a kid before dinner, it spoils their appetite for more nutritious foods (Brown 2007).

Deer undergo two stress periods in the southern United States, one during late winter when fat stores have been depleted due to cold temperatures and natural foods are less available, and one during late summer/early fall when plants have ceased growth and have become unpalatable (Koerth and Kroll 1998). Acorns have not begun to fall during the latter stress period. To mitigate these periods of stress, a supplemental forage program could be instituted to provide year-round food for deer (Koerth and Kroll 1998) that are stressed. Improving the quality of forage during these stress periods should be the focal point. The strategically concentrated method of food plots (≤1%) should be continued on Amelia Springs. Soil tests, which Amelia Springs currently does, should establish proper fertilizer application rates for maximum plant growth.

An excellent spring/summer food crop would be to plant chicory mixed with a fall/winter food source such as oats, rye, wheat or clover. An optimal mix would be 2 lbs/acre chicory, 5 lbs/acre ladino clover, and 50 lbs/acre wheat (Kammermeyer 2003). Chicory is high in protein (20-30%) and used by deer mostly during the spring and summer. Although chicory has a high nitrogen requirement for maximum growth, the mixed planting with a nitrogen fixing legume like clover will offset some of the nitrogen requirements. The digestibility of chicory leaves is very high at 90-95% (Kammermeyer 2003). Chicory also can withstand high grazing, soybeans and cowpeas cannot and will die if overgrazed. This mixture of warm and cool season plantings should provide an
attractant for deer that will last throughout the hunting season as well as a year around food source for deer.

Hunter harvest

Current club regulations require 1) mandatory harvest of a doe after initial buck harvest; 2) a harvestable buck must have 18 inches of antler beam length, and 3) a maximum 3 buck limit consistent with state regulations. Based on the previous 3 years’ harvest data, the average harvest was 12.6 antlered males per season for an antlered harvest rate of 21% based on the 3-year average antlered population size generated by this study. If the objective is to produce mature bucks, only 10-20% of the antlered male segment should be harvested (Jacobson and Guynn 1995). A slight decrease in harvest should be considered to fall within these guidelines. Capping hunter buck harvest at 2 per hunter/season might be an alternative to stay under the guidelines thereby not restricting everyone when the maximum number is reached. Antlerless harvest rates based on this study are at the level needed to achieve a buck:doe ratio of 1:2, I recommend a continuance of current antlerless harvest levels (~30) annually. Accidental harvest of button bucks will occur, but efforts should be made to restrict it to the lowest possible level. Another possible improvement to consider would be to have hunt club directors have a meeting and explain very concisely what the expectations of adult male sizes are as well as acceptable harvest sizes of adult bucks using examples from pictures and harvested antlers. A VDGIF biologist could be invited to field any questions/concerns. During this study, a few members had unreasonable expectations and “friendly arguments” about proper management ensued, leading to some dissension in the group. Misconceptions about quality deer management result from several things, especially
poor communication among hunters and biologists. When that is added to a program attempting to manage a natural resource (deer), it compounds the problem, resulting in disgruntled and frustrated hunters (Van Brackle and McDonald 1995). A more efficient program occurs when all members are “on board” with the values and goals of the QDM program.

**Hunter tactics**

Hunting tactics on Amelia Springs also could be altered. Permanent stands are scattered throughout the woods of Amelia Springs hunt club and most of these stands have been up for years. These stands receive the majority of hunting pressure experienced by Amelia Springs hunt club and are very useful in harvesting the antlerless, but not antlered, segment of the population. The results of this study suggest that deer avoid areas frequented by hunters and stick to areas of little or no hunting pressure. Kroll (1994) notes that bucks quickly learn the location of stands and take avoidance maneuvers by the third day of occupation, and stands that have been in the same location for years are avoided entirely. I agree with Kroll (1994) that the best method to harvest a mature buck is by using a highly mobile, non-permanent stand or blind. Deer know every detail within their home range and anything out of the ordinary will immediately draw their attention. Hunters also need to adjust to a buck’s changing activity pattern. Thus, I recommend that hunters be more mobile and depend upon permanent stands only as areas to harvest antlerless deer. Hunters should not hunt the same stand day after day, but rather move according to wind conditions. They should scout out areas other hunters are not using and set-up with a mobile stand. These hunting methods should prove more effective in harvesting a mature buck.
Figure 5.1. Examples of large male white-tailed deer living on Amelia Springs hunt club, Amelia County, Virginia, that were not observed by hunters during the hunting seasons in 2003-2005.
Figure 5.2. Examples of older aged male white-tailed deer who have passed their prime and whose antlers have degraded, at the Amelia Springs hunt club, Amelia County Virginia, 2003-05.
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Appendix A. White-tailed deer home range size (ha) reported by geographic region

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual Home Range Size (ha)</th>
<th>Summer Home Range Size</th>
<th>Winter Home Range Size</th>
<th>Sex</th>
<th>Source</th>
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<tbody>
<tr>
<td>South Dakota</td>
<td>-</td>
<td>598</td>
<td>277</td>
<td>M</td>
<td>Griffin et al. (1999)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>743</td>
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<td>-</td>
<td>F</td>
<td>Filipiak et al. (1996)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>252</td>
<td>-</td>
<td>-</td>
<td>M</td>
<td>Nelson (1979)</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>New York</td>
<td>221</td>
<td>-</td>
<td>132</td>
<td>F</td>
<td>Tierson et al. (1995)</td>
</tr>
<tr>
<td></td>
<td>231</td>
<td>-</td>
<td>150</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>Mississippi</td>
<td>691</td>
<td>-</td>
<td>-</td>
<td>M</td>
<td>Vanderhoof and Jacobson</td>
</tr>
<tr>
<td></td>
<td>343</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td>(1993)</td>
</tr>
<tr>
<td>Florida</td>
<td>700</td>
<td>-</td>
<td>-</td>
<td>M</td>
<td>Sargent and Labisky</td>
</tr>
<tr>
<td></td>
<td>290</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td>(1995)</td>
</tr>
<tr>
<td>Texas</td>
<td>139</td>
<td>-</td>
<td>-</td>
<td>M</td>
<td>Inglis et al. (1979)</td>
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<tr>
<td></td>
<td>84</td>
<td>-</td>
<td>-</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Georgia</td>
<td>127</td>
<td>-</td>
<td>-</td>
<td>M&amp;F</td>
<td>Kammermeyer</td>
</tr>
<tr>
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<td>-</td>
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<td>-</td>
<td>M&amp;F</td>
<td>Marchinton (1976)</td>
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<tr>
<td>Virginia</td>
<td>444</td>
<td>-</td>
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<td>F</td>
<td>Scanlon and Vaughan</td>
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<td>(by habitat)</td>
<td>1864</td>
<td>-</td>
<td>-</td>
<td>M</td>
<td>(1985)</td>
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<td>1586</td>
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<td>-</td>
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<td></td>
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<td>879</td>
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### Appendix B. Trap Data Sheet

**Capture Conditions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Free Range</th>
<th>Rocket Net Location</th>
<th>Rocket Net UTM</th>
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</table>

<table>
<thead>
<tr>
<th>Cloud Cover (%)</th>
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<th>50</th>
<th>75</th>
<th>100</th>
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<tbody>
<tr>
<td>Precip</td>
<td>none</td>
<td>drizzle</td>
<td>rain</td>
<td>snow</td>
<td>sleet</td>
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<tr>
<td>Ground</td>
<td>dry</td>
<td>damp</td>
<td>wet</td>
<td>snow</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Wind</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Dir</th>
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<tbody>
<tr>
<td>Start Time</td>
<td>______________</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Military</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire Time</td>
<td>______________</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finish Time</td>
<td>______________</td>
<td></td>
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</tr>
<tr>
<td>Total # Deer Seen</td>
<td>_____________</td>
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**2004 Trap Data Sheet**

<table>
<thead>
<tr>
<th>Deer</th>
<th>Age</th>
<th>Sex</th>
<th>Freq.</th>
<th>Left Ear Tag 1</th>
<th>Right Ear Tag 2</th>
<th>Re-Capture</th>
<th>Beam Length L (mm)</th>
<th>Beam Length R (mm)</th>
<th>Circumference L (mm)</th>
<th>Circumference R (mm)</th>
<th># Antler Points</th>
<th>Chest Girth(mm)</th>
<th>Hair Sample</th>
<th>Comments (over if needed)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>J</td>
<td>A</td>
<td>M</td>
<td>F</td>
<td>Y</td>
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<td></td>
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<tr>
<td>2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Include on Map:**

1) Wind Direction
2) Draw deer movements, including
   a. # of deer in group
   b. Time seen
   c. Whether or not they were captured
3) Draw in woods, ponds, stand location, etc.

<table>
<thead>
<tr>
<th>Deer #</th>
<th>Telazol</th>
<th>Injection</th>
<th>Immobilized</th>
<th>Recovery</th>
<th>Time</th>
<th>Time</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injury</th>
<th>Treatment</th>
<th>Euthanized?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# net
Appendix C. Strength of signal and confidence factor ratings

Strength of signal (SS):

1. Signal can be heard with antennae and antennae wire removed from receiver. This will only occur when close to the animal.

2. The signal is very loud with little static. Usually this means you are less than 500 meters from the animal.

3. The signal is strong, but there is static present. The signal persists even if the animal is moving rapidly.

4. The signal is weak, but consistent. Usually the signal will come in only if you are pointed in the direction of the animal. Readings should only be taken under this condition either to get an idea where the animal is or when there is no other way to get closer to the animal.

5. The signal is faint and very broken. This occurs when the animal is almost out of range and/or moving rapidly in broken terrain. You will often lose the signal and then pick it back up.

Confidence factor (CF):

1. Should be reported only if the reading is confirmed by a visual sighting of the animal.

2. Used when you are very confident about the reading. This should be used when the animal is close and the terrain and angles were good.

3. Used when you are confident about the reading but there were some less than ideal conditions. Examples include, terrain causing signal bounce, animal moving rapidly or time interval between readings was greater than 20 minutes.

4. Used when you have a less than ideal readings and don’t feel confident about your readings. For example, angles were good but animal was far away (signal strength) and the terrain was broken.

5. Used when you don’t have much confidence in the reading. This usually occurs when most of the conditions were poor (time, terrain, distance and angles). Use this when you feel the reading probably should not be used in home range analysis.

Adapted from Cooperative Allegheny Bear Study (CABS) telemetry protocol.