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Population characteristics of a white-tailed deer herd in an industrial pine forest of north-central Louisiana

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POPULATION CHARACTERISTICS OF A WHITE-TAILED DEER HERD IN AN INDUSTRIAL PINE FOREST OF NORTH-CENTRAL LOUISIANA

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ABSTRACT

White-tailed deer are the most important game species in Louisiana, and throughout the southeastern United States. Likewise, the forest products industry represents the most important agricultural commodity in Louisiana, and industrial landowners frequently lease their properties to sportsmen specifically for white-tailed deer hunting. I conducted research assessing survival, space use, and habitat selection of white-tailed deer on a 3885 ha industrial forest owned by Plum Creek Timber Company. I captured 61 deer in Union Parish, Louisiana in 2009-2010, radio-marked 24 females and 23 males, and ear-tagged 7 females and 6 males. Season and sex interacted to affect home range and core area sizes. Males home range sizes varied seasonally and were 232 ha, 70 ha, and 129 ha for spring, summer, and fall respectively. Female home range sizes did not differ seasonally and were 104 ha, 90 ha, and 62 ha for spring, summer, and fall respectively. Forest openings were important to both sexes when establishing home ranges. Core area selection exhibited a season and sex interaction as both sexes shifted selection in the fall to 0-4 year old pine and 13-19 year old pine stands. Use of habitats within home ranges did not vary by sex, season, or an interaction between them. Males and females chose 5-12 year old pine stands consistently across all seasons. Survival differed by season, but not by sex. Survival rates for adult males in spring, summer, and fall were 0.95, 0.97, and 0.54 respectively. Survival rates for females were 0.95, 0.97, and 0.56 for spring, summer, and fall respectively. All fall mortality was hunting-related, whereas mortalities during spring and summer resulted from unknown causes. The extensive use of bait, primarily corn and rice bran, was thought to influence space use and survival, and further research is needed to determine the effects of baiting on susceptibility of harvest of different age classes and sexes.

INTRODUCTION

White-tailed deer are the most sought after big game species in the southeastern United States. Market hunting in the early 1900s reduced deer densities throughout the South, but restocking efforts allowed populations to dramatically rebound. Nationally, big game hunters numbered 10.7 million in 2006 and spent $11.8 billion on their expeditions (U.S. Fish and Wildlife Service 2006). In Louisiana, $286,233,000 was spent by 204,000 big game hunters representing 195,200 harvested deer (U.S. Fish and Wildlife Service 2006) in 2006. More recently, deer harvest in Louisiana has declined 24.5% with only 147,300 animals being harvested in the 2009-2010 season (personal communication, Scott Durham, Louisiana Department of Wildlife and Fisheries).

Forestry represents Louisiana's top cash crop and a $3.1 billion dollar industry in 2010 (Louisiana Forestry Association 2011). Much of the forest industry of the southeast and Louisiana is industrial pine forest consisting of propagated loblolly pine (*Pinus taeda*). Plantations are often intensively managed even-aged stands with short stand rotation lengths (Gresham 2002). Chemical site treatments of fertilizer and herbicides are often used to maximize stand productivity and timber value. However, repeated herbicide applications can lead to floristic diversity being suppressed up to 15 years when both woody and herbaceous plants are controlled for a 3-5 year establishment period (Miller et al. 2003).

Many timber companies lease expansive tracts of property to recreational clubs for hunting purposes to increase revenue. Leasers in conjunction with state and private wildlife biologists are often allowed to manage wildlife populations to a varying degree. Many clubs enroll in a Deer Management Assistance Program (DMAP) which allows for additional harvest of females and provides assistance from a state biologist to reach management goals. Traditional harvest techniques focusing on the harvest of any age class male and female are often practiced on these leases. However, as the idea of Quality Deer Management (QDM), which protects young males and promotes the harvest of adult females, continues to gain popularity over traditional harvest strategies so does the increase in lease prices and expectations for harvesting larger antlered males.

The use of natural and artificial bait to aid in the harvest and observability of white-tailed deer is a common practice throughout much of the southeast. In Louisiana, the use of artificial bait (e.g., corn, rice bran, dried soybeans, etc.) is legal and widely practiced among hunters. Bait has been linked to changes in space use by deer (Kilpatrick and Stober 2002), habitat alterations due to increase browsing at bait stations (Doenier et al. 1997, Garner 2001), an increase in potential disease transmission from increased contact (Garner 2001, Rudolph et al. 2006), and an increase in hunter harvest of deer (Frawley 2002, Kilpatrick et al. 2010).

Ecology of white-tailed deer has been studied throughout its geographic range. In northern latitudes deer are considered migratory, experience severe winter weather, and face predation from large carnivores (Verne 1973, Zagata and Haugen 1974). In southern ranges deer are more sedentary, experience less severe winter weather and fewer if any larger predators (Marchinton and Jeter 1966, Byford 1969). These factors influence space use, habitat selection, and annual survival.

Estimates of space use (e.g., home range, core area) vary widely throughout the southeast (42 – 3,614 ha; Lewis 1968, Mott 1981, Herriman 1983, Morrison 1985, Hellickson et al. 2008, Karns 2008, Thayer 2009). These studies have occurred in many habitat types, but in Louisiana and adjacent states with similar habitats (e.g., Mississippi), most work has been confined to bottomland habitats. Bottomlands are considered high quality habitat for deer (Stransky 1969), but the distribution of these forests is limited whereas industrial pine forests comprise a large percentage of available habitat for deer. Deer inhabit many kinds of habitats including mesquite dominated forest in central Texas (Brunjes et al. 2006), tamarack swamps in south-central Wisconsin (Larson et al. 1978), various coniferous forests in northern Idaho (Pauley et al. 1993), and cedar swamps in Minnesota (Rongstad and Tester 1969) but there is a lack of information detailing habitat selection within industrial pine forests.

Many recent studies reporting survival rates have been conducted on areas practicing a QDM management regime and focus on producing mature males (Ditchkoff, et al. 2001, Bowman et al. 2007, Thayer et al. 2009). Predation (Nelson and Mech 1986, DeYoung 1989), vehicle collisions (Miller et al. 2003, Thayer 2009), disease (Miller et al. 2003), male aggression (Thomas et al. 1965) and hunting (Fuller 1990, Nelson and Mech 1986) are sources of white-tailed deer mortality across their range. Variability in survival rates reported in the southeast (44%-91%; DeYoung 1989, Ditchkoff et al. 2001, Bowman et al. 2007, Thayer et al. 2009) are dependent upon sex, age, season, and density (Gavin et al. 1984, Whitlaw et al. 1998, DelGiudice et al. 2002).

An earlier study in bottomland forests of south-central Louisiana (Thayer et al. 2009) indicated that estimates of space use were among the smallest reported in the deer literature. Likewise, survival rates of males were approximately 50% annually, despite antler restrictions designed to increase survival of males. The Louisiana Department of Wildlife and Fisheries (LDWF) recognized the immense variability in habitats across physiographic regions of Louisiana, and the relevance of collecting science-based information to improve management of deer throughout the state. Specifically, industrial pine forests comprise substantial portions of north-central and southeast Louisiana, and the highest annual deer harvest occurs in Union

Parish, which is dominated by upland pine forests managed for wood fiber production. Therefore, my research was initiated to collect baseline information on ecological characteristics of deer populations in an industrial forest. Specifically, my objectives were to evaluate space use, habitat usage, and survival of adult male and female white-tailed deer within an industrial pine forest in north-central Louisiana.

STUDY AREA

This project was conducted on 3,885 ha of upland pine forest owned by Plum Creek Timber Company in Union Parish, Louisiana (Figure 1). The area was composed primarily of loblolly pine plantations harvested on an approximately 25 year rotation. First thinning of plantations occurred between ages 13-15 with a second thinning between 17-20 years. Fertilization through aerial application commonly occurred after each thinning. Most stands were 24-29 ha in size and maximum stand size did not exceed 49 ha. Site preparation included rowing site debris into raised beds before planting and an herbicide application to reduce competition from woody plants.

Dominant overstory species consisted of loblolly pine, bald cypress (*Taxodium distichum*), white oak (*Q. alba*), willow oak (*Q. phellos*), water oak (*Q. nigra*), sweetgum (*Liquidambar styraciflua*) and black gum (*Nyssa sylvatica*). Midstory species consisted of red maple (*Acer rubrum*), hickory (*Carya* spp.), American holly (*Illex opaca*), sweetgum, and oaks (*Quercus* spp.). Common understory species included beggars lice (*Desmodium* spp.), switchgrass (*Panicum* spp.), goldenrod (*Solidago* spp.), blackberry (*Rubus* spp.), rattan vine (*Berchemia scandens*), greenbrier (*Smilax* spp.) Japanese honey-suckle (*Lonicera japonica*), muscadine (*Vitis* spp.), French mulberry (*Callicarpa americana*), Carolina buckthorn (*Rhamnus caroliniana*), blueberry (*Vaccinium* spp.), and Virginia creeper (*Parthenocissus quinquefolia*). Forest openings (e.g., gas pipelines, gas well sites, recent logging decks, forest roads) were usually planted as food plots consisting of ryegrass (*Lolium* spp.), clover (*Trifolium* spp.) or wheat (*Triticum* spp.).

Figure 1. Location of study site chosen to investigate space use, survival, and habitat selection of white-tailed deer in industrial pine plantations in Union Parish, Louisiana, USA, 2009-2011.

The area was accessible through improved and unimproved roads including state highway 143, which bordered the eastern edge of the site. Bayou DeLoutre comprised the western boundary and Ford Road served as the northern boundary, whereas Phillips Ferry Road was the southern boundary. Buffalo Hole Road traversed the site as well as 5 other secondary roads. Traffic on all roads was light and localized.

The study area was leased by 2 individual clubs (Buffalo Hole and Ten Mile Creek; Figure 2). These clubs leased approximately 1,536 ha and 2,347 ha respectively with 97 members total. Deer harvest guidelines were similar in each club; members were allowed to harvest 3 antlerless and 3 antlered deer corresponding with state regulations. Buffalo Hole has participated in of the Louisiana Deer Management Assistance Program (DMAP) since 1981, whereas Ten Mile Creek chose to only keep club harvest records. Average annual deer harvest over the last 10 years for the study site was 95 females and 106 males. Union Parish reported the highest total harvest for the state on private lands in 2009 with 6668 animals harvested (Louisiana Department of Wildlife and Fisheries, unpublished data).

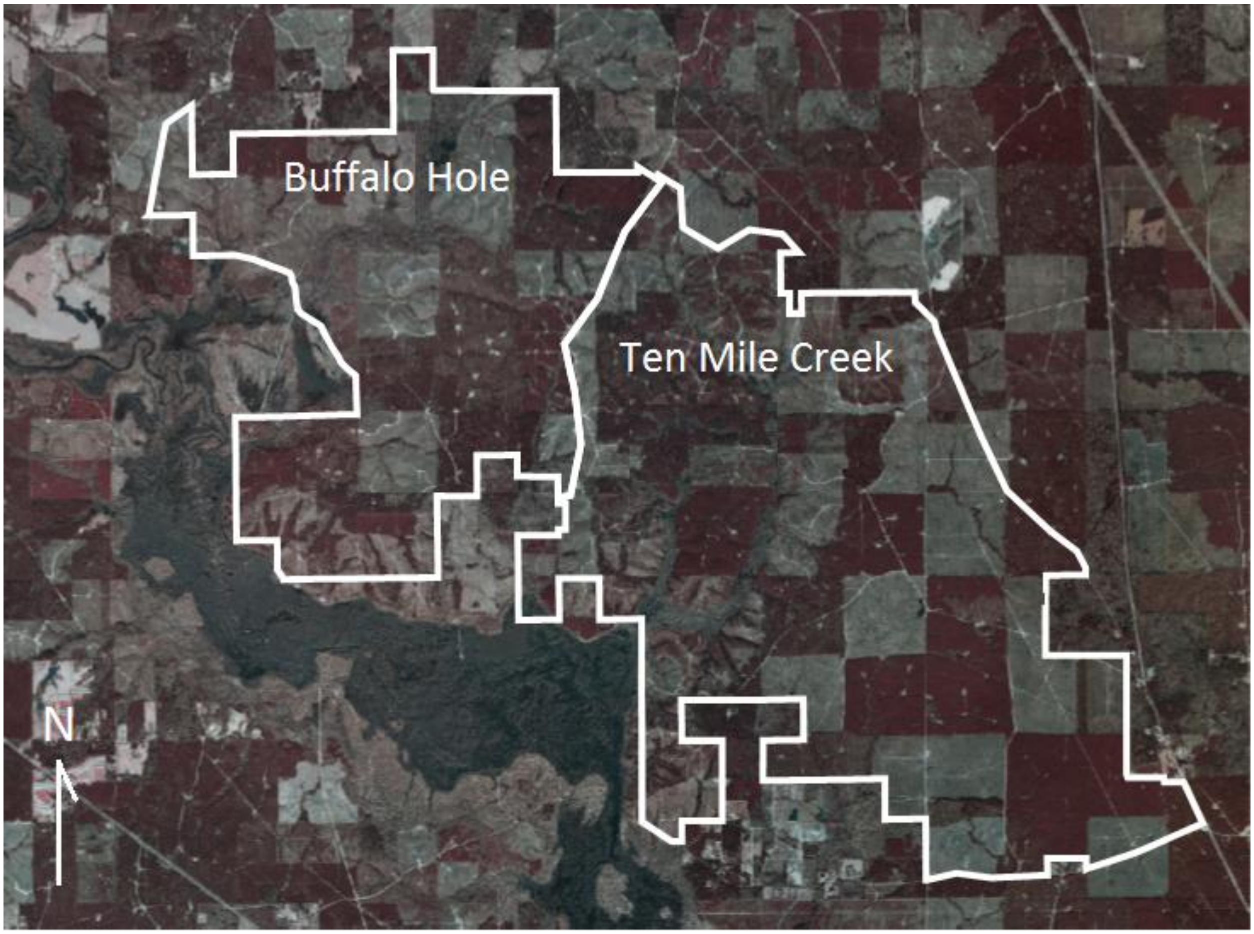

Figure 2. Boundary lines of Buffalo Hole and Ten Mile Creek hunt clubs chosen to investigate space use, survival, and habitat selection of white-tailed deer in industrial pine plantations in Union Parish, Louisiana, USA, 2009-2011.

Herd health data collected from hunter harvested adult females (n=10) in 2009-2010 indicated a fetus/doe ratio of 1.2, average weight of 110lbs, kidney fat index of 71.9%, 70% observable conception rate, and average conception date of November 24. Browse surveys conducted in June 2010 indicated low browse pressure on most desirable stems (black gum, rattan vine (*Berchemia scandens*), *Smilax* spp.) and an overall browsing index that was on the low in the desirable range (Louisiana Department of Wildlife and Fisheries, unpublished data).

A week long camera survey performed in early fall 2007 consisting of 24 camera sites indicated a deer density of 1 deer per 7 ha with a buck:doe ratio of 0.96 (Louisiana Department of Wildlife and Fisheries, unpublished data).

The study area experienced multiple severe prolonged weather events during 2009-2011. In early fall 2009 (September-October) the study area and the surrounding region experienced significant precipitation (≥16 inches more than long term monthly average) resulting in the flooding of the Ouachita River, Bayou de Loutre, and multiple portions of the study area. During the summer of 2010 a lack of precipitation and high summer temperatures resulted in a prolonged drought in the study area and surrounding areas.

METHODS

Deer were captured with drop nets during the winter/spring (January-March) and summer (July-September) in 2009-2010 at permanent bait sites (*n*=14) using whole kernel corn and rice bran. Trapping sites were constructed in previously used logging decks and planted with rye grass during fall. Sites were separated by at least 0.4 miles and were distributed throughout the study area in multiple age class forest stands and along pipe lines.

Captured deer were chemically immobilized using an intramuscular injection of 5 mg/kg Telazol (Fort Dodge Animal Health, Fort Dodge, Iowa) and 2.49 mg/kg Xylazine (Phoenix Scientific, St. Joseph, Missouri) at the dosage of 1 ml per 38.5 kg (Amass and Drew 2006). Vital signs including heart rate, rectal temperature, and respiratory rate were monitored on immobilized deer every 5-10 minutes from capture until release. After processing was complete, deer were injected intravenously with Tolazoline (100 mg/ml, Tolazine®; Lloyd Laboratories, Shenandoah, Iowa) at 3.0 mg/kg and released at the capture site.

While deer where immobilized, all were marked in both ears with numbered Monel ear-tags (National Brand and Tag Company; Newport, Kentucky) to allow for later identification at time of harvest. Sex, weight, estimated age, and antler characteristics were also recorded for each deer. Age was estimated from tooth replacement and wear techniques (Severinghaus 1949) and deer were categorized as fawns, 1.5 or ≥2.5 years of age. Expandable VHF radio-collars (Mod M4230B; Advanced Telemetry Systems, Isanti, Minnesota) were placed on yearling 1.5 yr old deer in an attempt to allow for growth of the animal. We placed 400-gram VHF radio-collars (Mod M2510B; Advanced Telemetry Systems, Isanti, Minnesota) on adults which constituted <1% of adult deer body weight. All radio-collars were equipped with an 8-hour time-delayed motion sensor to detect mortalities.

Immobilization of captured deer occurred within 2-5 minutes of capture with a total duration time of 120 minutes. Stress was reduced with rapid immobilization, the use of eye ointment and blindfolds, and sternal or right side placement of the animal. The primary researchers attended a Safe Capture class in Baton Rouge, Louisiana to ensure proper chemical immobilizations of deer (Amass and Drew 2006). Capture and handling procedures occurred under Louisiana State University Agricultural Center Institutional Animal Care and Use Protocol (AE2009-18).

Locations of radio-marked deer were calculated using triangulation (Cochran and Lord 1963) from 3-5 fixed telemetry stations (n= 138) with an ATS R2000 receiver (Advanced Telemetry Systems Inc., Isanti, Minnesota) and a hand-held 3 element Yagi antenna. Locations were obtained 1-5 times per week using 3 bearings taken within a 20 minute interval to minimize error associated with deer movement. Telemetry error was calculated with >50 bearings per observer, per season on dummy radio collars that were placed at neck height of deer. Radio locations were withheld from observers to simulate actual telemetry. The average angle of error was ±7.1°

If a mortality signal from the radio-collar was detected, homing was used to locate the radio-collar or perished animal and a hand-held GPS unit was used to record the coordinates. If the animal had perished every attempt was made to determine the cause of death. Hunters were asked to view radio-collared animals just like all other animals in an attempt to limit bias and to report harvest of all radio-collared and ear-tagged animals. When radio-collared animals were observed visually during telemetry or by chance, exact locations were recorded.

Monitoring periods of telemetry were divided into 3 seasons: spring (February 1-May 30) summer (June 1 – September 30) and fall (October 1 – January 31). Seasons were determined based on biological cues of deer (fawning, breeding) and the hunting season in the study area (October 1 – January 31).

Seasonal Space Use

Location of a Signal software (LOAS, Version 4.0 Ecological Software Solutions 1999) with the maximum likelihood estimator method was used to estimate Universal Transverse Mercator (UTM) coordinates and error eclipse areas from the recorded telemetry bearings. Locations on individual deer were separated by a minimum of 8 hrs to provide some measure of independence and only locations with an error eclipse areas <1 ha were used in the analyses. Only animals with ≥18 locations per season were included in the home range analysis based on observation curves constructed on 16 animals (8M, 8F). Locations were then imported into ArcMap 9.2 (ESRI, Redlands, California) where they were converted to point themes. Using the Home Range Tool application, estimates of home range (95%) and core area (50%) were calculated using an adaptive-kernel analysis (Worton 1989) in conjunction with the likelihood cross-validation method (Silverman 1986).

A factorial analysis of variance (ANOVA) using Proc Mixed was used to test for season by sex interactions in home range and core area sizes with SAS V9.2 (SAS Institute, Inc. 1996). A one-way ANOVA was used to test for effects of year on home range and core areas. Additionally, LSMeans was used to test for effects of season and sex on home range and core area size when no significant difference occurred in the factorial analysis. All age classes were collapsed for analysis because of 1) relatively low sample sizes within older age classes of males and 2) a skewed age ratio in females towards older individuals. Statistical differences were considered significant at $P < 0.05$.

Habitat Selection

Plum Creek provided land cover maps containing stand size, age, species planted and habitat type (commercial pines, gas lines, gas wells, bottomland hardwoods, roads etc) for the study area. Commercial pine stands were further separated based on age, stand structure and commercial management activities (thinning, herbicide application, harvest). Habitats were classified as 0-4 year old pine, 5-12 year old pine, 13-19 year old pine, ≥20 year old pine, hardwoods, and forest openings (roads, pipelines, natural gas well sites, forest paths). Habitats classified as 0-4 year old pine included stands recently harvested (bare ground), newly planted, and whose overstory was still open. The 5-12 year old pine stands consisted of established growing trees (≥3m) including those experiencing canopy closure and up until the first thinning. Often these stands initially had dense understories which were later shaded out due to canopy closure. Pine stands old enough to receive a first and second thinning were classified 13-19 year old pine. The ≥ 20 year old pine stands were those eligible for harvest under normal harvest conditions and usually contained dense herbaceous and woody understories.

Home ranges, core areas, and point themes were intersected with land cover maps using ArcView to quantify seasonal habitat use. Compositional analysis was used to determine habitat selection at 3 scales: home ranges vs. habitats available in the study area (1^{st} order), core area vs. habitats available in the home range (2^{nd} order; Aebischer et al. 1993), and locations vs. habitats available in the home range (3^{rd} order; Chamberlain and Leopold 2000). When a habitat was not available at a given scale the value of 0.7 was inserted to minimize Type I error (Bingham and Brennan 2004). Differences of log-ratios of habitat use and availability percentages were examined using a multivariate analysis of variance (MANOVA) with sex, season, and sex and season interaction as the main effects (Aebischer et al 1993). When significant differences between habitat availability and selection were found, a ranking matrix of t-tests was constructed to determine order of habitat selection.

Survival

Program MARK was used to model survival rates of adult radio-collared deer seasonally using a known fate model. Encounter histories for all adults were constructed for the 24 month period between February 2009 and January 2011. Deer that were monitored during both years of the study were considered 2 separate samples in the analysis.

I applied 5 candidate models to determine effects of season, sex, and their interaction on survival rates. Models included:

1. S (.) – Survival is constant across seasons and sex
2. S (t) – Survival is not constant across seasons
3. S (g) – Survival is not constant by sex
4. S (t*g) – Survival is not constant across seasons by sex
5. S (t+g) – Survival is not constant across seasons and sex

Akaike's information criterion (AIC_c), change in $AIC_{c,}$ Δ AIC_c values, and Akaike weights (AIC_w) were used to determine which candidate model was the best fit (Anderson et al. 2000). Age was not included as an effect in the models because most males in the dataset were in younger age classes, whereas most females were in older age classes. Because of small sample sizes of ear-tagged deer, these individuals (fawns) were not included in the program MARK analysis. Rather, the proportion of these individuals recovered and/or assumed to be alive at the end of the study are reported, and should be viewed as a maximum number due to lack of monitoring capabilities except for hunter reported harvests.

RESULTS

Seasonal Space Use

A total of 61 deer (29 M, 32 F) were captured with 47 (23 M, 24 F) receiving radio-collars and 13 juveniles (6 M, 7 F) receiving only ear-tags. Locations of radio-collared animals resulted in 146 seasonal home ranges (69 M, 77 F). Home range ($F_{1/138}$ = 0.37, *P*= 0.545) and core area ($F_{1/138}$=0.66, *P*=0.418) sizes did not differ by year, therefore data were pooled to examine potential differences by season and sex. Season and sex interacted to influence home range ($F_{2/139}$ = 7.03, *P*= 0.001) and core area ($F_{2/139}$ = 8.55, $P \leq$ 0.001; Table 1) sizes.

Home range ($F_{2/73}$=8.57, $P \leq 0.001$) and core area ($F_{2/65}$=10.25, $P \leq 0.001$) size varied seasonally for males. Males maintained 230% and 80% larger home ranges in spring than in summer (t_{139}=-2.98, $P \leq 0.003$) and fall (t_{139}=5.10, $P<0.001$), respectively. Core area size during fall was greater than during summer (366%; t_{139}=5.65, $P<0.001$) and spring (113%; t_{139}=-3.53, $P<0.001$). The longest documented movement of a male was of a 1.5 year old male moving 12.3km. Fall home range (83%; t_{139}=2.41, $P \leq 0.017$) and core area (67%; t_{139}=2.40, $P<0.018$) size in males was also larger than in summer. Female home range ($F_{2/73}$=1.26, *P*=0.2891) and core area ($F_{2/73}$=0.89, *P*=0.4153) sizes did not differ across seasons. The longest documented movement of a female was 6.8km by a 4 year old female.

Table 1. Mean seasonal home range (HR) and core area (CA) size (ha) with associated standard errors (SE) of adult radio-marked white-tailed deer in Union Parish, Louisiana USA, 2009-2011.

Season	**Sex**	**HR ± SE**	**CA ± SE**
Spring	M	231.8 ± 145.8	39.2 ± 25.2
	F	104 ± 76.4	15.9 ± 15.1
Summer	M	70.2 ± 55.6	8.4 ± 6.6
	F	89.7 ± 84.9	13.6 ± 13.8
Fall	M	128.7 ± 147.3	18.4 ± 27.2
	F	62.2 ± 69.5	9.6 ± 9.8
Yearly	M	169.8 ± 76.6	14.9 ± 14.5
	F	111.8 ± 119.7	13.4 ± 13

Habitat Selection

All 123 home ranges and core areas were used to assess seasonal habitat selection in males and females. Habitats selected when establishing a home range relative to habitats available in the study area varied by sex ($F_{5/115}$=8.99, $P \leq 0.001$; Table 2) but not season ($F_{10/226}$=0.98, P=0.464) and season and sex did not interact to influence habitat selection ($F_{10/222}$=0.82, P=0.609). Selection of forest openings by males when establishing home ranges differed statistically from 13-19 year old pine in spring (t=6.88, $P \leq 0.001$), summer (t=5.27, $P \leq 0.001$), and fall (t=4.86, $P \leq 0.001$). Female selection of forest openings also differed statistically from 13-19 year old pines across all seasons (spring, t=5.07, $P \leq 0.001$; summer, t=82.99, $P \leq 0.001$; fall, t=50.35, $P \leq 0.001$).

Sex and season interacted ($F_{10/222}$=2.51, P=0.007) to influence the composition of core areas in relation to habitats available within home ranges. Males selected hardwoods in the summer, and females selected 13-19 year old pine stands (versus hardwoods; t=3.94, $P \leq 0.001$). Both males and females shifted selection in the fall to 0-4 year old pine and 13-19 year old pine stands.

Use of habitats within home ranges did not vary by sex ($F_{5/111}$=0.38, P=0.859), season ($F_{10/222}$=0.35, P=0.965) or their interaction ($F_{10/222}$=0.61, P=0.802). Both males and females consistently used 5-12 year old pine habitat across all seasons. Habitat composition of the study area consisted of 8.6% 0-4 year old pine (334 ha), 41.6% 5-12 year old pine (1616 ha), 2.3% 13-19 year old pine (89 ha), 24% ≥20 year old pine (932 ha), 17.8% hardwoods (692 ha), and 5.1% openings (198 ha).

Survival

Survival rates were based on 23 males and 24 females resulting in 64 encounter histories. Of the 23 males radio-collared, 12 (52%) were harvested by hunters, 3 (13%) died of unknown

Table 2. Seasonal and mean ranks (1 = lowest, 5 = highest) of habitat selection across 3 spatial scales (habitat selection in home ranges vs. habitat availability across study area [1st order], habitat selection in core areas vs. habitat availability across home ranges [2nd order], and habitat used vs. habitat availability across home ranges [3rd order]) based on compositional analysis of male and female white-tailed deer in Union Parish, Louisiana, USA 2009-2011.

Sex		1st Order Season				2nd Order Season				3rd Order Season			
	Habitat Type	Spring	Summer	Fall	Mean	Spring	Summer	Fall	Mean	Spring	Summer	Fall	Mean
Male	0-4 yr. Pine	1	2	3	2	0	0	4	1.33	1	1	2	1.33
	5-12 yr. Pine	5	3	2	3.33	5	5	1	3.67	5	5	5	5
	13-19 yr. Pine	0	0	0	0	2	2	5	3	3	3	4	3.33
	≥20 yr. Pine	2	1	1	1.33	1	1	3	1.67	0	4	3	2.33
	Hardwoods	3	4	4	3.67	3	4	2	3	2	2	1	1.67
	Forest Opening	4	5	5	4.67	4	3	0	2.33	4	0	0	1.33
Female	0-4 yr. Pine	2	4	2	2.67	1	1	4	2	0	0	1	0.33
	5-12 yr. Pine	3	3	3	3	5	4	1	3.33	5	4	4	4.33
	13-19 yr. Pine	0	0	0	0	3	5	5	4.33	2	5	3	3.33
	≥20 yr. Pine	1	2	1	1.33	2	0	3	1.67	4	2	2	2.67
	Hardwoods	4	1	4	3	0	2	2	1.33	3	3	5	3.67
	Forest Opening	5	5	5	5	4	3	0	2.33	1	1	0	0.67

causes and 4 (17%) lost their transmitters. Of the 24 females radio-collared, 10 (42%) were harvested by hunters, 3 (13%) died of unknown causes and 1 (4%) lost its transmitter. Hunting accounted for all mortality in the fall in males and females with 20 (91%) deer being harvested at bait stations. Unknown causes accounted for all mortality in the spring and summer in both sexes. Of the 6 deer found dead of unknown causes, 5 (83%) had been scavenged prior to radio-collar retrieval. At the conclusion of the study 4 (17%) males and 10 (42%) females were actively being monitored.

The best fit model showed survival did differ across seasons but not by sex (Table 3). Mean annual survival was 0.51 (SE= 0.03) during 2009-2011. Survival was lower in the fall (S=0.54 SE=0.07) than in spring (S=0.95 SE=0.03) and summer (S=0.97 SE=0.02) in males. Females followed a similar trend with lower survival in fall (S=0.56 SE=0.06) than spring (S=0.95 SE=0.03) and summer (S=0.97 SE=0.02).

Of the 13 (6 M, 7 F) ear-tagged only animals, 4 (3 M, 1 F) were reported as harvested (31%). The lone female marked only with ear-tags and subsequently harvested was 1.5 years old and taken within 275 m of her capture location. Two males were harvested as 1.5 year olds and had moved 2.64 km and 12.26 km away from their capture sites. The remaining ear-tagged only male was harvested as a 2.5 year old and had moved 1.56 km away from his capture site.

Table 3. Output from 5 a priori candidate models used to estimate survival rates for white-tailed deer from radio-telemetry data in Union Parrish, Louisiana, USA from 2009-2010.

Model	**AICc**	**Δ AICc**	**AICc Weight**	**K**	**Deviance**
S (t)	173.6405	0	0.67162	3	0.4788
S (g+t)	175.3130	1.6725	0.29103	4	0.0831
S (g*t)	179.4194	5.7789	0.03735	6	0
S (.)	231.0979	57.4574	0	1	62.0207
S (g)	232.8221	59.1816	0	2	61.7112

DISCUSSION

<u>Space Use</u>

Comparing estimates of space use to previous studies is tenuous due to variation of estimation methods, sampling methods, intensity and accuracy of monitoring, and sample size. Nonetheless, space use in my study exceeded that reported in south Louisiana (Thayer 2009), but was less than other studies conducted in the southeast (Ivey and Causey 1981, Mott 1981, Herriman 1983, Morrison 1985, Hellickson et al. 2008, Karns 2008).

Males and females consistently exhibited greatest space use during spring. Male space use increased 80% from fall to spring, and was likely influenced by dispersal of 1.5 year olds, resource depletion, and physiological demands of new antler growth. Yearling males often exhibit their greatest movements during spring (Hawkins et al. 1971, Nelson and Mech 1984). Females increased space use by 62% in spring, which was likely attributable to the search for food resources and the cessation of their family group for fawning (Schwede et al. 1993, DeYoung and Miller 2011). Early spring coincides with a depletion of quality browse and a lack of hard mast availability as well as the cessation of baiting by hunters. These factors coupled with depleted fat reserves from a possible extended breeding season may cause deer to increase space use in search of food resources (Nelson and Mech 1986).

Space use and movements during summer were similar in both sexes, likely in response to increased browse availability, lack of human disturbance, and climatic factors (Beier and McCullough 1990). Later summer drought conditions likely degraded browse conditions throughout the study area. Daily movements by females were likely impeded by the presence of fawns (Bertrand et al. 1996, D'Angelo et al. 2004), and decreasing space use at a time of high metabolic demand because of lactation and antlerogensis in males could have been offset by the quantity of browse available (Beier and McCullough 1990). Likewise, reductions in space use during summer for males may be a response to reduced aggression towards conspecific males (Thomas et al. 1965) and the aggregation of males (Hirth 1977).

The increased male movement in fall coincides with a decline in browse quality, dispersion of males from summer aggregations and the onset of breeding season (Thomas et al. 1965, Hirth 1977, Ivey and Causey 1988). Sedentary movement by females during fall could be an attempt to be more available to males as reported in Holzenbein and Schwede (1989). With an increased effort by hunters to harvest adult females to reduce overall density on the study area, females may have become more sedentary resulting in the energy-efficient breeding behavior observed by Kolodzinski et al. (2010).

Baiting for hunting purposes and to supplement poor food sources, can alter deer movements and increase use of areas close to bait sites (Kilpatrick et al. 2010). In years of severe winters, deer are known to increase supplemental feed use but still prefer to use natural browse (Doenier et al. 1997). In Michigan, Garner (2001) reported that deer exhibited high fidelity for baited areas but not to specific baiting stations, which is consistent with the lack of female movement in the fall observed in my study. Increased human disturbance in the form of hunting activities, ATV use, and road traffic likely confined space use by deer in fall in attempt to avoid interactions (Kilgo et al. 1998).

<u>Habitat Selection</u>

All habitat types were not readily available to all radio-collared deer likely influencing habitat selection analysis. Forest openings were important to deer when selecting a home range, likely related to the importance of browse species associated with edges (Poteet et al. 1986). Intensively managed pine stands similar to those on my study area are characterized by a noticeable reduction in browse species as stands succeed and the canopy closes (Scanlon and Sharik 1986, Edwards et al. 2004). Therefore, deer likely maintain home ranges in a way that maximizes access to consistent browse. Secondarily, during fall hunters typically placed bait in forest openings to maximize harvest opportunities. The presence of bait during fall likely contributed to selection of openings when establishing and maintaining home ranges.

Hardwood forests in the study area were limited to streamside management zones and provided the only source of natural hard mast available in fall. These forests were selected by both sexes throughout the year when establishing home ranges. During times with high summer temperatures and regular periods of drought, hardwood forests associated with riparian areas may be used for access to shade, water, and cooler temperatures (Tucker 1981, Poteet et al. 1996). Newly planted pine stands (0-4 years old) were also selected by females during summer at a home range scale likely due to high browse availability and cover selected during fawning.

At successively smaller spatial scales, 5-12 year old pine stands and 13-19 year old pine stands were important to both sexes, presumably, due to the dense understory in these stands that are commonly used as bedding cover (Larson et al. 1978, Brunjes et al. 2006) and escape cover from hunting pressure (Naugle 1994). Hunting pressure has been shown to shift habitat use (Kammermeyer and Marchinton 1976) and cause animals to move farther into cover away from human disturbance (Naugle 1994). These pine stands were often juxtaposed to pipeline and forest openings with readily accessible bait in fall, likely increasing use (Kilpatrick et al. 2010).

Pine stands that had been thinned (13-19 years old) and fertilized offered an increase in available browse and cover for both sexes (Edwards et al. 2004). In fall, both sexes shifted core area selection away from 5-12 year old pine stands to 0-4 year old and 13-19 year old pine stands. This shift is likely attributable to a lack of forage available due to canopy closure in 5-12 year old pine stands (Edwards et al. 2004). Notably, locations recorded on individual deer (3rd order selection), of both sexes indicated consistent selection of 5-12 year old pine stands during all seasons, likely due to the dense security and bedding cover available within these stands.

The observed importance of forest openings to deer when selecting home ranges and apparent lack of use of openings (3rd order selection) may be an artifact of biases associated with radio-tracking. As such, the observed importance of openings at smaller spatial scales may be under-estimated. I personally observed marked and un-marked deer using openings on numerous occasions from a distance of several hundred meters, but they would then move into adjacent escape cover. Likewise, most openings on the study area were narrow (30-50 m) and, linear, therefore telemetry error could have resulted in deer locations being assigned to adjacent forest stands when they instead actually occurred within openings.

Survival

Similar to other studies, survival during fall was considerably lower than during the spring and summer (Bowman et al. 2007, Thayer et al. 2009). High mortality rates for adult male deer have been attributed primarily to hunting (Nelson and Mech 1986, Fuller 1990) with yearling and 2.5 year-old males being more susceptible to harvest than mature males (McCullough 1979, Nelson and Mech 1986). Movements linked to dispersal also limit survival of 1.5 year old deer by exposing them to new unfamiliar territory and risks (Holzenbein and Marchinton 1992). The annual harvest rate for 1.5 year-old and 2.5 year-old radio-collared males (56%) was similar to rates previously reported by Nelson and Mech (1986; 68%), and Nixon et al. (1991; 66%) and greater than Ditchkoff et al. (2001; 26%), and Bowman et al. (2007; 46%). Significant harvest of 1.5 year-old and 2.5 year-old males over an extended period of time can skew age class structure towards younger males, as evidenced on my study area (Miller et al. 1995).

Older age class males accounted for a small percentage of the overall harvest on the study area. Age classes were not included in the survival models but of the 4 males ≥3.5 years old that were monitored, 2 were harvested outside of their previously documented home ranges during the breeding period, similar to findings reported by Bowman et al. (2007). Mature males have been shown to maintain smaller home ranges but increase movements in the fall, increasing their vulnerability to harvest and contact with other adult males, which may lead to male aggression-related mortality (Thomas et al. 1965).

Different harvest strategies (QDM, traditional) should influence survival rates, however, survival of males were similar to those reported by Thayer et al. (2009). Even with harvest restrictions protecting young males under QDM, ≥2.5 year old males suffered a 45% mortality rate from hunting in south Louisiana (Thayer et al. 2009). This mortality rate is similar to the 49% hunting mortality rate of ≥1.5 year old males observed in my study, which occurred under a traditional management regime where males are harvested regardless of age-class.

Annual survival of adult females (51%) was lower than survival rates previously reported (65-90%; Gavin et al. 1984, Fuller 1990, Nixon et al. 1991, Land et al. 1993, DePerno et al. 2000, Hansen and Beringer 2003). Harvest records from my study area indicate that females were harvested with almost equal frequency as males and usually of older age classes. Females were harvested at a rate of 1:16 ha over the last 10 years, which corresponds to DMAP suggestions for a moderate density herd (personal communication, Scott Durham, Louisiana Department of Wildlife and Fisheries).

Mortality rates caused by variables other than hunting were similar to those reported in previous studies (7-15%; DeYoung 1989, Ditchkoff et al. 2001, Bowman et al. 2007). Although a number of gravel and paved roads transected the study area, no radio-collared deer died as a result of a vehicle collision that has been reported in other studies (Hansen and Beringer 2003, Thayer et al. 2009). The amount of mortality due to predation is unclear because 83% of the deer dying of unknown causes in my study area were scavenged prior to me locating their carcasses. Coyote scat and tracks were found at every scavenged carcass site and coyotes represent a significant threat to fawn and adult survival (Carroll and Brown, 1977, Whittaker and Lindzey 1999). However, coyotes are also widely known to forage by scavenging (Chamberlain and Leopold 1999). An unscavenged, adult female recovered during a summer drought period approximately 3.36 km away from her documented home range was thought to have died from Hemorrhagic Disease (HD) based on a field autopsy.

I offer that the high hunting/fall mortality is partially influenced by the availability of bait during the summer and fall. Bait began to appear in the landscape in August and persisted through the end of hunting season (January 31). All radio-collared deer had multiple permanent stands and bait stations inside their fall home ranges. Of the 22 radio-collared deer that were harvested, 20 (91%) were harvested at bait stations. Both animals that were not harvested with the aid of bait were older males (≥3.5) harvested during the breeding period. Additional research is required to further quantify the effects and influences of baiting on susceptibility to harvest for an individual deer. An experimental study with animals under similar harvest conditions and varying availability to baiting could be beneficial.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Thousands of acres of upland hardwoods and mixed hardwood-pine stands have been converted to industrial loblolly pine plantations in the southeast. Although white-tailed deer ecology has been studied across its range, there is a lack of information concerning its ecology in an industrial pine setting. My estimates of seasonal space use suggest intensively managed pine plantations can offer suitable habitat for white-tailed deer. Seasonal home ranges of both sexes were smaller than most previously reported findings in the southeast, further indicating the potential for increased management activities in pine plantations and on smaller tracts of property (>200 ha).

Even-aged plantations undergo a series of successional stages from planting to final harvest. At any point in time and at any scale, habitat suitability of a stand varies for white-tailed deer. Minimizing canopy closure and increasing browse availability are essential in maintaining habitat in pine plantations. Continuing the rotational harvest and the size of clear cuts (49 ha) found in the study area could increase the diversity of juxtaposed stands ensuring availability of forage and cover.

Annual survival of males and females was low in comparison to other studies with most mortality attributed to hunter harvest. The small amount of non-hunting mortality indicates that if deer are not harvested they have a high probability of advancing in age class. If hunters and wildlife managers wish to increase survival of 1.5 year old males, which would be critical in facilitating the change in age class structure exhibited on my study area, management practices should be scrutinized. Educating hunters about aging deer and selectivity at harvest could improve age structure of the herd. Similar fall survival rates of males to those reported in Thayer et al. (2009) suggest that protecting immature males through antler restrictions under a QDM management regime may be ineffective.

In addition, the use of bait to aid in harvest and the susceptibility of younger age class deer to this technique should be examined. Future research should focus on an animal's susceptibility to harvest in baited versus unbaited areas under similar harvest and management strategies based on age and sex characteristics. The cessation of baiting in my study area could allow for an increase in 1.5 year old male survival, but could diminish adult female harvest opportunities, which are necessary for effective herd management. Bait undoubtedly influences harvest rates and seasonal movements as well as potentially increasing the risk for disease transmission, but to what extent in southeastern deer populations is unknown.

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