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Abstract: We monitored white-tailed deer (*Odocoileus virginianus*) use of riparian zones (RZs) and adjacent pine plantations of 3 age classes (young, l-3 years old; intermediate, 5-7 years old; and older, 9–13 years old) using radio telemetry for 2 years on a l ,300-ha study area near Alto, Texas. Riparian zones comprised 22.0% of the area; young, intermediate, and older pine plantations comprised 19.1%, 45.7%. and 13.2%. respectively. Based on data from 4 to 9 deer the first year and 12 to 17 deer the second year, home ranges averaged 103, 71.95, and l 14 ha during spring, summer, fall, and winter, respectively, and were composed primarily of intermediate-age plantations and RZs. Deer showed significant preferences for intermediate-age pine plantations during all seasons and for RZs during fall and winter. Older plantations produced little forage due to canopy closure, and were generally avoided throughout the year. Young plantations, which provided the most forage but the least cover, received relatively light yearlong use and were a minor component of deer home ranges. For females and young males, this study demonstrates that, where available, RZs may comprise an important component of deer home ranges in intensively managed forests.

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More than 180,000 ha in the South are planted to pine annually, usually following the clearcutting of second-growth forests (Scanlon and Sharik 1986). During harvest, retention of mature forests along natural drainages is a recommended practice. These forests remnants, often referred to as riparian zones, streamside management zones, hardwood stringers, or buffer strips, are retained by the U.S. Forest Service and many

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forest industry companies to reduce soil erosion and enhance wildlife habitat and plant diversity (Wigley and Melchiors 1994).

Despite federal and forest industry policies that encourage or require retention of RZs, few empirical data are available to demonstrate their importance to wildlife (Wigley and Melchiors 1994). Research has verified the importance of RZs to squirrels (*Sciurus* spp.) (Warren and Hurst 1980) and wild turkeys (*Meleagris gallopavo*) (Burk et al. 1990), but we are unaware of any studies documenting the importance of RZs to deer. However, the importance of water in their habitat has been suggested. In Oklahoma, Ockenfels (1980) found increased use of riparian habitats when ambient temperatures exceeded 30 C. Tucker (1981) concluded that deer preferred dense stands close to water during summer in eastern Texas. Rayburn (1983) found a significant positive correlation between frequency of deer summer use and nearness of habitat to open water in eastern Texas.

This study was initiated to document the importance of RZs to white-tailed deer in eastern Texas. We collected 2 years of deer telemetry data from a forested matrix of RZs and pine plantations. We tested the null hypothesis that observed and expected seasonal habitat use by deer did not differ for RZs and adjacent pine plantations of 3 age classes.

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Methods

Study Area

The study was conducted on the 1,300-ha Glen A. Stanley Hunting Club, 11 km southwest of Alto in Cherokee County, Texas. This site contained a mosaic of pine plantations of different ages and an extensive, well dispersed system of RZs (Fig. 1). The site is characterized by gently rolling hills, intermittent streams (except for Wire Creek which typically Rows yearlong). and well- to moderately well-drained upland soils (Poteet 1990). The 1- to 13-year-old pine plantations that occupied the site at study initiation had been established by clearcutting, site preparation (shearing and windrowing, or broadcast burning). and planting of loblolly pine (*Pinus taeda*) seedlings, usually on a 3.7- × 1.3-m spacing. The study area was classified into 4 habitat types: (1) young plantations (YP), 1-3 years old; (2) intermediate-age plantations (IP), 5-7 years old; (3) older plantations (OP), 9-13 years old; and (4) RZs. The YP, comprising 19.1% of the study area, consisted of pine seedling/sapling stands and provided an abundance of deer forage but only limited cover. The IP, comprising 45.7% of the area, afforded an abundance of both forage and cover. The OP, comprising 13.2% of the area, had reached total crown closure; these stands provided thermal and hiding cover but little forage. Dominant woody species included American beau-

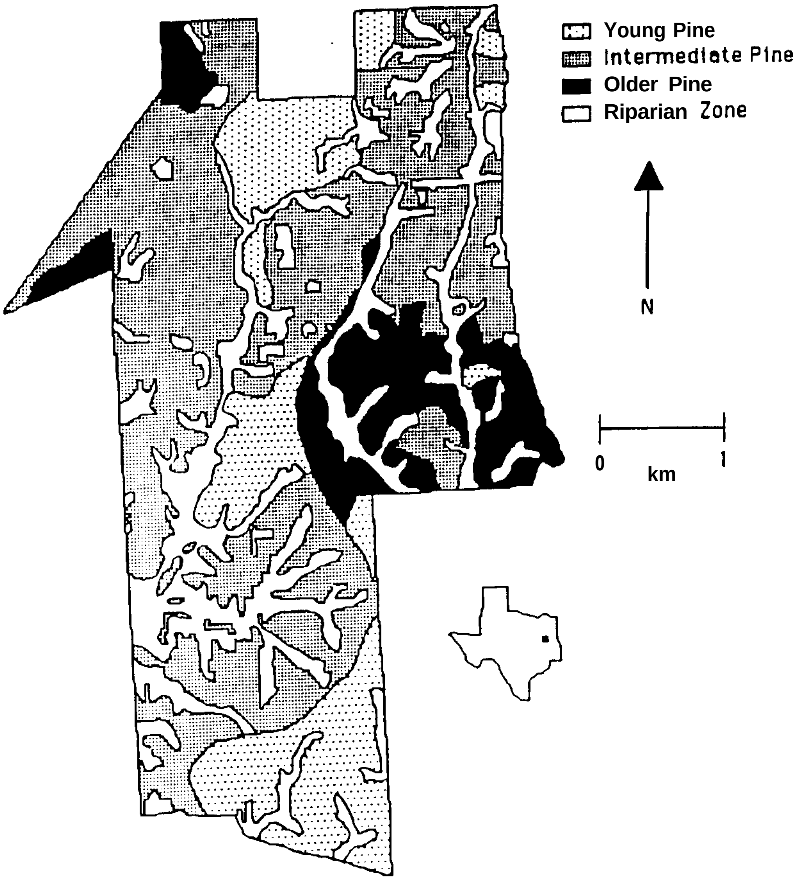

Figure 1. Location of young, intermediate-age, and older pine plantations and riparian zones on the Glen A. Stanley Hunting Club study area in eastern Texas.

tyberry (*Callicarpa americana),* blackberry and dewberry (*Rubus* spp.), and winged sumac (*Rhus copallina*).

Riparian zones comprised 22.0% of the study area. Some merchantable pines and hardwoods were removed when adjacent stands were harvested, but the RZs received no subsequent management. Dominant overstory trees within the RZs included sweetgum (*Liquidambar styraciflua*), white oak (*Quercus alba*), southern red oak (*Q. falcata*), and blackgum (*Nyssa sylvatica*).

Deer Capture

We captured deer using drop nets and box traps during January and February 1988 and February and March 1989 (Poteet 1990). We moved nets and traps periodically to improve trapping success and to ensure broad coverage of the study area.

Deer were sexed. aged as adult or fawn, fitted with a 30-month radio transmitter (with a 6-hour mortality sensor), and released at the site of capture.

Telemetry Procedures

A horizontal-control land survey was conducted to establish a meter-based x-y coordinate system for antenna and known-location transmitter beacons. Twenty-seven antenna stations. generally located at the highest available elevations, were established throughout the study area to ensure full coverage. Five permanent antennae (on 15.2-m rotating masts) and 6 portable antennae (on 4.6-m masts) were utilized. When necessary, portable units were moved to previously surveyed points to minimize error polygons. Each antenna unit consisted of a vertically-oriented, 2-element yagi antenna mounted on each end of a 2-m horizontal cross boom equipped with a null combiner (Medina and Smith 1986).

Radio tracking was conducted from 1 March 1988 through 28 February 1990. Each observer began each tracking session by obtaining azimuths for 2-5 known-location beacons. These azimuths were then compared to the true azimuths. If azimuths from a particular tower were consistently higher or lower than the known azimuths, a correction factor was determined for that tower. This correction factor was then applied to all tower-to-deer azimuths for the remainder of that tracking session. This procedure was repeated each time an observer moved to a new station. Using 2-way radios for communication, animal locations were estimated using simultaneous fixes from 3 antenna stations. These locations were entered into a portable micro-computer for processing using a triangulation software package (TRIANG) and evaluated for accuracy (Lenth 198 l). Field locations were considered tentatively acceptable if the 3 azimuths appeared to intersect at a common point on the screen of the micro-computer. Locations not meeting this criteria were repeated periodically throughout the hour until the azimuths appeared to intersect at a common point. This often required moving one or more observers to different antenna stations.

The 24-hour day was divided into 3 8-hour time periods and tracking sessions were scheduled to obtain an equal number of locations in each period. Four g-hour tracking sessions were conducted each week. Tracking sessions were rotated among weeks so that each time period was represented twice a week during 2 of 3 consecutive weeks. Efforts were made to maintain a 3- to 4-hour time lapse between successive locations of each animal. Approximately 4-8 locations per animal were obtained each week for 2 years.

Error testing was conducted throughout the study to assess accuracy of the telemetry system (Poteet 1990). Transmitters were placed at 4 known locations and station-to-transmitter azimuths were obtained simultaneously from 3 antenna stations. These error-check locations ($N = 101$) were also processed using the Andrew's estimator (Lenth 1981). Estimated x and y coordinates for each location were then compared to known coordinates and standard errors were calculated for the set of test locations.

Data Analyses

Color infrared aerial photographs (1:6,000 scale) were used to develop a map of the study area delineating habitat types. This map was digitized, transformed into a 300 x 300 computerized grid cell system (each cell approximately 0.1 ha in size), and processed with the Map Analysis Package software (MAP) (Berry 1986) to classify grid cells by habitat type. To ensure conservative estimates of RZ use, grid cells containing a RZ and another habitat type were assigned to the non-RZ type. The resulting map served as a base map for subsequent overlaying of deer locations and home range ellipses.

The calendar year was divided into 4 seasons: spring (Mar-May), summer (Jun-Aug), fall (Sep-Nov), and winter (Dee-Feb). Deer locations were grouped by season and processed using the Andrew's estimator to obtain the estimated x-y location coordinates and the size of the 95% contidence ellipse (Lenth 1981). Findings presented here correspond to Design 2 of Thomas and Taylor (1990), where availability of each habitat type was assumed equal for all animals according to its proportion within the study area. Location estimates for each deer were overlaid onto the study area map and the percent use of each habitat was estimated. Habitat use and availability data then were paired. Results were pooled across individuals to obtain an overall vector of use and availability for each season (Poteet 1990).

Chi-square goodness-of-fit tests were used to determine if deer demonstrated habitat selectivity or simply occupied available habitat types in proportion to their occurrence. To determine whether use of individual habitats by season was more or less than expected (henceforth referred to as preference or avoidance, respectively), 95% simultaneous confidence intervals were employed (Neu et al. 1974, Byers et al. 1984). Statistical tests were performed at the 0.05 level of significance.

The multivariate Omstein-Uhlenbeck diffusion process model, which does not assume independent locations (Dunn and Gipson 1977), was used to delineate home ranges. Only those location estimates having a confidence ellipse of <l .OO ha were used in this analysis (Poteet 1990).

Results

Thirty-two deer (19 in 1988, 13 in 1989) were radio collared during this study. We used data for 24 of these deer in the habitat preference analysis. Of these, 17 were females (4 were fawns at capture) and 7 were males (6 were fawns at capture). The number of usable locations/deer for the 2 years combined averaged 5 l, 54, 66, and 53 for spring, summer, fall, and winter, respectively.

Of approximately 4,900 deer locations obtained, 4,663 were considered acceptable by contidence ellipse criteria. Approximately 4,200 of these were used in the analysis; the remainder either fell outside the study area or were for deer that either lost their collars or died shortly after release. Average confidence ellipse size for all deer locations used in our analyses was 0.40 ha (SD = 0.19). Average confidence ellipse size for 101 error check locations, obtained from 4 known-location beacons, was 0.40 ha (SD = 0.12). Comparison of the estimated coordinates with the known coordinates resulted in a standard error of 48 m in each axis.

All acceptable locations were grouped by season and analyzed separately by year and with years combined. Differences between observed and expected habitat use were significant ($P <$ 0.001) for all seasons for combined and individual years

(Table 1). For combined years, the OP and YP habitat types were avoided during all seasons, the IP type was preferred all seasons, and RZs were preferred during fall and winter (Table I).

Results of the analyses for individual years generally supported the combined-year results (Table 1). With 3 exceptions, selectivity patterns displayed by deer during the first year were identical to those of the combined years. With 1 exception, selectivity patterns exhibited the second year (when numbers of deer and locations increased substantially) were identical to those of the combined-year data set.

Within seasons, home range sizes were very similar between years, averaging 97. 67, 101, and 109 ha for spring, summer, fall, and winter the first year, and 105, 72, 91, and 117 ha the second year, respectively. Home ranges typically incorporated several habitat types, but were composed primarily of RZs and IP (Table 2). Computation of 95% confidence intervals around the mean percent availabilities of each habitat type within the home ranges revealed that observed availabilities were significantly different (higher for IP and RZs, lower for YP) than expected for 3 of the 4 habitat types (Poteet 1990).

Table 1. Seasonal habitat use of riparian zones and adjacent young, intermediate-age, and older (1–3, S-7, and 9-I 3 years old, respectively) pine plantations by white-tailed deer in eastern Texas from March 1988 through February 1990.

Year Season	N Deer	N Locations	Hahitat type: Riparian zone	Pine plantation: Young	Pine plantation: Interm.	Pine plantation: Older	Chi-square'
1988							
Spring	12	301	* (25.6)[b]	– (3.5)	+ (55.2)	* (15.7)	so.97
Summer	10	357	* (28.4)	– (6.8)	+ (58.8)	– (6.0)	47.57
Fall	10	521	+ (37.5)	– (6.7)	+ (49.5)	– (6.4)	81.23
Winter	8	205	+ (41.4)	– (5.6)	* (41.7)	* (11.4)	36.82
1989							
Spring	19	877	* (22.R)	– (13.1)	+ (58.2)	– (5.9)	96.44
Summer	18	730	* (24.1)	– (15.4)	+ (54.9)	– (5.6)	67.83
Fall	18	731	* (22.X)	– (15.1)	+ (56.2)	– (5.9)	74.94
Winter	13	480	+ (29.7)	- (8.8)	+ (56.9)	– (4.6)	8 I.37
1988 and 1989 combined							
Spring	31	1,178	* (23.9)	– (9.3)	+ (57.0)	– (9.7)	112.29
Summer	28	1,087	* (25.6)	– (12.3)	+ (56.3)	– (5.7)	103.99
Fall	28	1,252	+ (28.0)	– (12.1)	+ (53.X)	– (6.1)	131.68
Winter	21	685	+ (34.2)	– (7.6)	+ (51.1)	– (7.2)	103.60
Study area availability (%)			22.0	19.1	45.7	13.2	

[a]All chi-square values are significant ($P < 0.001$).

[b]Preference, avoidance, and non-selection are denoted by +, –, and *, respectively. Values in parenthesis are percentages of locations.

[c]Percent availability of each habitat type across the entire study area.

Table 2. Composition (% ± SE) of white-tailed deer home ranges in eastern Texas by season and habitat type averaged across years.

Season	*N* deer	Riparian zones (22.0)[a]	Pine plantations Young (19.1)	Intermediate (45.7)	Older (13.2)
Spring	21	24.5 ± 2.8	12.1 ± 3.2	49.5 ± 3.7	13.9 ± 4.0
Summer	17	25.9 ± 4.1	7.3 ± 3.5	58.1 ± 4.1	8.8 ± 2.6
Fall	23	29.0 ± 3.8	8.0 ± 3.2	54.3 ± 4.0	X.6 ± 2.7
Winter	20	29.1 ± 4.1	x.2 ± 3.0	53.4 ± 4.0	9.3 ± 3.3

[a]Percent availability of each habitat type across the entire study area.

Discussion

Prior to canopy closure, pine plantations produce diverse and abundant deer forage (Scanlon and Sharik 1986). Avoidance of the YP type all seasons both years was unlikely related to forage availability, as the YP type provided the most forage (Harper 1990), but the least cover. Due to the abundance of forage in the YP type, deer possibly used the edges of these plantations and acquired necessary forage in a short time, thereby minimizing the probability of radio-locating them in this type. Average yearlong use of the YP increased from 5.6% to 13.1% from the first to second year, perhaps due to the increased height and density of the planted pines and native vegetation that occurs with normal stand development.

Avoidance of the OP type likely is attributed to a lack of forage due to canopy closure (Harper 1990). Forage availability in the OP type decreased from 2.6 kg/ha during the 1988–89 winter to 1.7 kg/ha during the following winter (Harper 1990), and average use of OP decreased from 11.4% to 4.6% during these consecutive winters.

Preference for the IP habitat is most likely attributable to the combination of forage availability and cover, The IP habitat ranked second in winter forage availability during both years and winter crown closure was ocularly estimated at 60% (Harper 1990). Despite droughty conditions and an increase in crown closure during the second year that reduced winter forage availability by approximately 70% (Harper 1990), average percent use increased by approximately 5.3%, with most deer spending >50% of their time in IPs. The fact that deer spent so much time in these plantations, despite reduced forage availability the second year, suggests that the deer were not only feeding in these plantations but also utilizing them for other activities. However, unless the IP stands are thinned, we predict less use as crown closure increases.

Preference shown for RZs during fall and winter may have been related to mast availability. Hard and soft mast have long been recognized as an important food source for white-tailed deer (Lay 1965). On the study area, production of hard mast was limited to RZs. Harper (1990) found limited hard mast (180 g/ha, dry weight) in RZs but none in plantations during late winter 1988–89. In late winter 1989-90, she found no hard mast anywhere. However, during years of limited mast production, it can be assumed that any mast present is quickly removed. Decreased use of RZs during the second fall (from 37.5% to 22.8%) and winter (from 41.4% to 29.7%) was possibly due to reduced mast availability.

Previous research (Ockenfels 1980, Tucker 1981, Rayburn 1983) suggests that water availability plays an important role in habitat selection by deer, especially during summer. Although observed use of RZs during summer was higher than expected both years of our study (1988: 28.4% versus 22.0%; 1989: 24.1% versus 22.0%). these differences were not significant.

We went to considerable expense and effort (precise land survey, large-scale aerial photography, 3 simultaneous fixes, repeated error testing, etc.) to minimize telemetry errors. Nevertheless, use of RZs was likely underestimated. Due to our arbitrary assignment of mixed-type grid cells, locations for deer using the edges of RZs may have been assigned to other habitat types. Furthermore, due to the long, narrow shape of the RZs compared to plantations (Fig. l), telemetry error was more likely to remove a location from a RZ than place it in one. In contrast, the larger plantation sizes enabled locations to be more accurately placed within them.

From regeneration to final harvest, even-aged plantations pass through a series of successional stages. At any point in time, habitat suitability varies for different wildlife species. Of the 3 plantation age classes available to deer in this study, the IP type was preferred. However, 3-4 years earlier, this habitat type would have been considered YP, and 3-4 years in the future, it would be considered OP, both of which were used less than expected based on availability. This demonstrates the importance of Juxtapositioning stand types and sizes, and scheduling harvest and intermediate treatments to ensure a sustained availability of stands that provide both forage and cover (Johnson 1987).

Our findings may not be applicable to mature bucks, because most of our animals were either does or young bucks. For does and younger males, this study demonstrates that RZs may comprise an important component of deer home ranges in intensively managed forests. However, when intensive timber management is not allowed in RZs, acreage is lost to timber production, and opportunity costs are incurred (Lickwar et al. 1992). Harvesting some timber from RZs can reduce these costs, and selective harvesting in RZs could be used to enhance diversity and production of mast-producing species (Melchiors and Cicero 1987). Opportunity costs associated with RZ retention also may be partially offset by leasing hunting opportunities, as leases with an abundance of wide RZs and mast-producing hardwoods should bring higher returns than those without RZs (McKee 1992).

Riparian zones enrich landscape floral and faunal diversity, and may provide critical sources of mature hardwoods, hard mast, and older-forest features (large den and cavity trees, large snags, coarse woody debris, etc.) that otherwise may be unavailable within intensively managed forested landscapes. Data presented here suggests that deer inhabiting such a landscape select home ranges comprised primarily of RZs and IP, and may display significant preferences for RZs during fall and winter.

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